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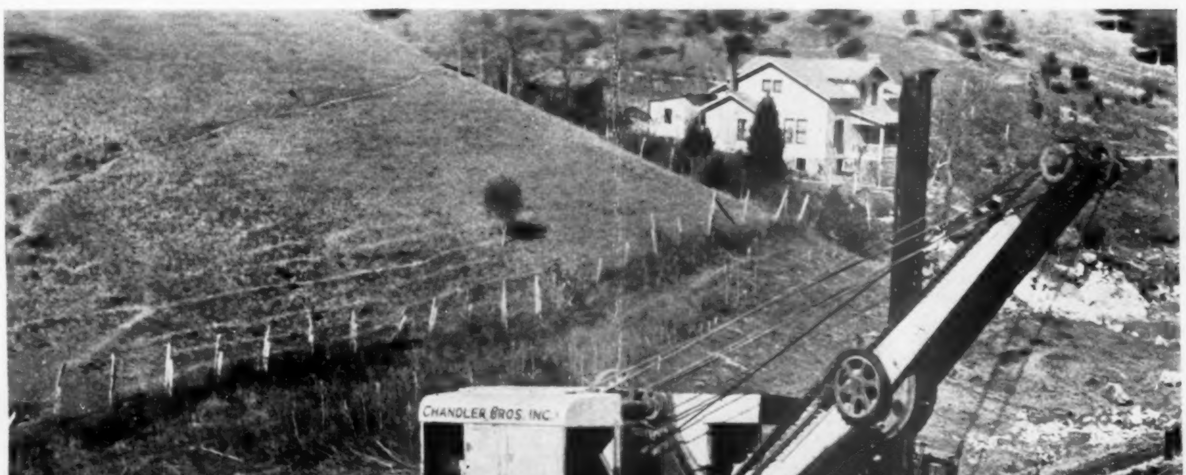

TYPICAL POWER-SHOVEL OPERATION

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G. P. St. CLAIR, *Editor*

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The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to described conditions

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POWER-SHOVEL OPERATION IN HIGHWAY GRADING

BY THE DIVISION OF MANAGEMENT, BUREAU OF PUBLIC ROADS

Reported by T. WARREN ALLEN, Chief, Division of Management, and ANDREW P. ANDERSON, Highway Engineer

PART 2.—THE HAULING

SHOVEL LOADING TWO 5-CUBIC-YARD WAGONS.

THE SHOVEL is the key unit in a power-shovel grading outfit as commonly operated on highway work, but ordinarily it functions only in coordination with the hauling equipment. Except where casting is possible, the shovel can dig material no faster than the hauling units can carry it away to the dump and can dig only when hauling units are in position to be loaded. A high rate of production is possible only with sufficient hauling units to carry the full output of the shovel. Operation of hauling units must be so coordinated as to proceed with almost clocklike precision and without the least interference in the steady operation of the shovel.

MAINTENANCE OF EXACT BALANCE BETWEEN SHOVEL AND HAULING UNITS A DIFFICULT PROBLEM

Attainment of a high degree of efficiency in the operation of the hauling units is not easy. Studies on a great many jobs indicate that the hauling equipment, either because of shortage or improper operation, is the most general cause of reduced production. From a study of more than a hundred power-shovel grading jobs, it was found that the average power shovel on highway grading jobs spent about 20 percent of its available working time in waiting for hauling units. A part of this time loss was unavoidable because of the nature of the work but most of the delays were avoidable and should never have been permitted to occur.

Elimination of all avoidable delays without incurring the cost of carrying too much hauling equipment during much of the time is probably impossible. This is largely because there are constant but irregular variations in the hauling distance. The number of hauling units required to maintain full shovel production varies almost directly as the length of haul. The length of haul on the average grading job often fluctuates between wide limits and at such frequent intervals that the maintenance of an exact balance is economically undesirable. The speed with which hauling can be done is also variable depending upon the condition of the roadway. High speeds are seldom possible and very low speeds are often necessary. To still further complicate an already difficult situation, the characteristics which affect the rate at which the material can be dug by the shovel sometimes also change with unexpected frequency.

Since the length of haul, road conditions, and the characteristics of the material are all subject to frequent change the maintenance of an exact balance between the shovel and the hauling equipment is generally impractical, especially on light work. Although perfect balance is impossible or impractical, there is the necessity for approaching this balance as closely as conditions permit. The closeness of approach will depend very largely upon the ease with which vehicles can be added and removed in conformity with the actual requirements as they occur on the job. On work within easy access of a source of truck or wagon supply, or on jobs using two or more shovels, conformity of supply to demand can be fairly close. Lack of balance on remote jobs forced to depend on a fixed number of hauling units will be measured largely by the range of fluctuation in hauling distances as fixed by the design. A general rule for such a condition is that the amount of hauling equipment should be such that the value of the occasional delays to the shovel in waiting for hauling equip-

ment should be equal to the value of the time spent from time to time by the hauling units in waiting for the shovel.

The operations of the hauling equipment consist of getting into position to receive the load, receiving it, taking it to the dump, dumping, turning at the dump, and returning to the shovel for another load. The time regularly consumed on each trip exclusive of the time of travel to and from the dump is called the "time constant" and is fairly uniform for any given type of equipment and set of operating conditions. Table 1 shows average time constants on a number of projects on which various kinds of vehicles of different capacities were used. The average values for the time constant as found on these jobs for the different operations vary considerably. This is to be expected. For example, the loading time will vary with the number of dipper loads required to the vehicle load, the kind of material handled, the skill of the shovel operator, and the numerous factors which affect the time of the shovel cycle.

While the time constant varies with many conditions, it is fairly uniform for a given set of conditions and its value on any job is easily determined by direct timing. It is an important factor in determining the number of vehicles most probably required to maintain a given rate of shovel operation.

TABLE 1.—*Average time constants for various types of hauling units based on operation with a 1- or 1¼-yard shovel*

Operation	7-yard tractor-drawn wagons	4½-yard trucks	2½-yard trucks	1¼-yard trucks
	Seconds	*Seconds*	*Seconds*	*Seconds*
Load	210	135	75	40
Turn	25	32	34	26
Unload	14	26	29	27
Turn	21	27	20	21
Waits or delays	80	55	50	44
Total	350	275	208	158

EFFICIENT OPERATION REQUIRES ATTENTION TO A NUMBER OF FACTORS

In highway grading work the time constant for the hauling units is of major importance. The hauls are generally short so that the actual speed of the vehicle usually has only a comparatively small effect as compared with the influence of the time constant. The time constant is made up of a number of individual items which are repeated with every load through the day. Their total for the day may therefore become very large.

Many contractors do not seem to realize the importance of saving seconds on the repetitive operations involved in the operation of the hauling equipment. Extension of the time constant by 2 minutes is as effective in reducing the output of the hauling equipment as an extension in the haul approximately equal to the average distance the vehicles traverse per minute of driving time. On many grading jobs the unnecessary extension of the time constant is far more than 1 minute.

Much of this delay can be eliminated by careful supervision of the operation of the hauling equipment, by keeping the traveled way in good condition, and particularly by giving attention to the conditions at the shovel and at the dump. "Bottle necks", a careless clean-up around the shovel, and restricted working area on the dump all tend to increase the time constant of the hauling equipment and thus adversely affect the output.

Another matter deserving attention is the load hauled per vehicle. There is considerable variation in the amount of material taken out per dipper load by a shovel. To place a given number of dipper loads in the vehicle on each trip is therefore a mistake, except possibly on very short hauls when there is a surplus of vehicles. Under normal road conditions, it takes as long to haul a half-loaded vehicle to the dump as it does to haul one that is fully loaded. On long-haul work there is much to be gained by hauling full loads, and the shovel operator should be charged with the responsibility of seeing that the vehicles leave the shovel properly loaded, no matter how many dipper loads are required. The hauling road should always be so maintained that full loads can be handled, especially on long hauls.

In selecting hauling equipment care should be taken to see that the units can be so handled that no single operation, such as turning, dumping, or maneuvering, will be likely to consume more time than is required for loading. Otherwise, this operation and not the shovel controls the job output. For ordinary highway grading, where fast shovel operation is so frequently possible, a hauling unit having a capacity of less than two dipper loads should never be considered. For ease in coordinating the operation of the hauling equipment so as to maintain fast shovel operation, the individual hauling units should carry three or more dipper loads. In general, the larger the capacity of the hauling units the more easily their operation can be properly supervised and coordinated, provided, of course, that they are otherwise adapted to the job.

The conditions under which the hauling equipment must operate are usually severe and frequently extremely difficult. Hauling equipment should be extremely strong and rugged and fully able to stand up under the most trying conditions. On the average grading job replacement of hauling units can seldom be made without incurring some delay to the shovel. Reliability is therefore a valuable asset.

BACKING OF TRUCKS TO DUMP OFTEN DESIRABLE

The hauling units must be provided with an abundance of power and with traction or road grip such as will permit the full utilization of this power under the most trying conditions. Grades as steep as 25 percent are not unusual, while slippery, rough, or yielding road surfaces are so common as to be almost the rule. For satisfactory operation, the hauling units must have capacity to carry at least two full dipper loads, must be extremely strong and dependable, and provided with ample power and traction to operate on grades and road surfaces much more difficult than those encountered in ordinary transportation. Two or three speeds in reverse are also desirable for such vehicles as trucks which are frequently backed to the dump. A fast and reliable dumping mechanism with a high dumping angle is a necessity.

On short-haul work trucks are often shuttled or backed from the shovel to the dump and then returned forward to the shovel. This eliminates two turns of the vehicle on each trip. Since each turn usually consumes from 20 to 40 seconds, this practice is advantageous until a distance is reached at which the time

lost in driving from the shovel to the dump in reverse instead of in forward is equal to the time saved by the elimination of the two turns. This is demonstrated as follows: Let—

L = the haul in feet at which shuttling the trucks ceases to be advantageous.

S = the speed in feet per minute of loaded trucks when driven forward from the shovel to the dump.

s = the speed in feet per minute of loaded trucks when backing to the dump.

K = the turning and maneuvering time in minutes saved on each round trip when trucks are backed instead of driven forward, or in other words, the difference between the time constants for trucks driven in the usual manner and when backed from the shovel to the dump.

Then $$L=\frac{KSs}{S-s} \qquad (1)$$

For example, if the average speed of the loaded trucks from shovel to dump is 500 feet per minute and their backing speed is 300 feet per minute, and the average difference between the truck time constants is 1 minute, then $L=\frac{1\times500\times300}{500-300}=750$ feet, which is the haul within which it is more advantageous to back the trucks than to drive them in forward. If the backing speed were only 200 feet per minute and the forward speed still 500 feet per minute, then the maximum haul to which the trucks could be backed with advantage would be only 333 feet. This illustrates the importance of a relatively high backing speed in extending the distance to which shuttling may be profitable. Trucks are now made with special provisions for driving in reverse both as to the ease and comfort of the driver and the number of speeds available. The actual backing speeds attained in the field with present equipment under various road conditions are shown in tables 2, 3, 4, and 5.

TABLE 2.—*Operating characteristics of heavy trucks having drive on all four wheels*

[Three 1¼-yard shovels on same job. All equipment in good condition. Material, earth and blasted rock. Grades mostly 5 to 10 percent. For all hauls below 600 feet, trucks backed to dump. Number of round trips timed, 639. Average load, pay yardage, 2.9 cubic yards]

Length of haul	Speed	
	Loaded	Return
	Feet per minute	*Feet per minute*
50 feet	210	260
100 feet	220	295
150 feet	250	302
250 feet	310	355
350 feet	365	400
450 feet	430	445
750 feet	510	420

Average time constant when trucks back to dump:	*Seconds*
Taking on load	88.6
Dumping	30.5
Waits and delays	23.8
Total	142.9

Working time lost by shovels

Class of time loss	Shovel no. 1	Shovel no. 2	Shovel no. 3
Minor time losses of shovels:	*Percent*	*Percent*	*Percent*
Hauling equipment, insufficient supply	4.1	2.5	5.4
Hauling equipment, operation	5.1	2.3	1.4
Moving shovel within cut	7.8	7.4	8.1
Shovel operator	2.4	2.1	1.3
Mechanical repairs or trouble with shovel	2.6	2.0	2.5
Sloping	3.9	2.9	4.1
Smoothing grade and loading pit	4.7	7.1	8.6
Checking grade	0.1		
Miscellaneous	8.7	7.8	8.2
Major mechanical repairs, shovel and cable	5.7	3.7	3.8

TABLE 3.—*Operating characteristics of heavy trucks on various lengths of haul*

[Trucks carried average loads of 2.5 cubic yards of pay material when working with a 1-yard shovel. All equipment in fair to good condition. Material mostly loam and clay, sticky and difficult to handle when wet. Loaded trucks backed to dump on all hauls below 750 feet]

Haul distance	Speed		Condition of hauling road
	Loaded	Return	
	Feet per minute	*Feet per minute*	
155 feet	315	325	Slippery, 10 percent grades.
225 feet	377	390	Mostly fair, light grades.
350 feet	435	535	Good.
420 feet	455	495	Fair, 5-percent grades.
510 feet	395	418	Fair, 10-percent grades.
620 feet	407	573	Mostly fair.
825 feet	660	615	Fair to good.
1,050 feet	515	443	Rough, poor.
1,135 feet	756	925	Fair to good.
1,250 feet	696	518	Fair to poor.
1,400 feet	594	550	Some very rough, 10-percent grade.

AVERAGE TIME CONSTANT

	Seconds
Taking on load	71.9
Turn (long hauls)	20.9
Dump load	28.8
Turn (long hauls)	18.7
Waits and delays	55.9
Total	196.2

WORKING TIME LOST BY SHOVEL

Minor time losses:	*Percent*
Hauling equipment, insufficient supply	14.9
Hauling equipment, faulty operation	4.5
Moving shovel within cut	5.2
Shovel operator	.7
Mechanical repair and trouble with shovel	.7
Sloping	3.7
Smoothing grade and loading pit	3.6
Major mechanical repairs to shovel and cable	3.3

SPEED OF HAULING UNITS VARIES WITH JOB CONDITIONS

When two or more shovels are used on the same job they should, if possible, be so located that hauling units can be readily exchanged between them, and every effort should be made to schedule the work so that when one shovel is on long hauls the other will be on relatively short-haul work. The hauling units can then be shifted in accordance with the actual requirements at the shovels. The total number of hauling units for the shovels should be the same as though each operated independently with one constantly on long hauls and the other on short hauls. By this method the working time of both the shovels and the hauling units can be utilized more fully. Since the equipment and the personnel remain constant, any increase in production obtained is practically a clear gain. Jobs have been found on which this simple expedient added nearly 10 percent to the average daily production.

Dressing Slopes by Hand and the Same Slope Five Days Later as Washed by Rain. Too Much Refinement Increases Cost Without Producing Advantages.

Table 4.—*Effect of length of haul and road condition on average hauling speed*

[2½-yard trucks in fair to good condition, working with 1-yard shovel. Common excavation. Hauls below 600 feet all by backing loaded trucks to dump]

Length of haul	Speed		Road condition
	Loaded	Return	
	Feet per minute	*Feet per minute*	
155 feet	373	423	Good.
170 feet	310	318	Fair surface, slippery steep downgrade.
200 feet	497	480	Good.
200 feet	250	362	Very rough.
210 feet	262	370	Poor road, rough with steep downgrade.
285 feet	427	427	Do.
350 feet	594	580	Good.
410 feet	524	530	Fair.
500 feet	292	600	Rough and slippery with 3 percent upgrade.
500 feet	518	700	Good to fair, nearly level.
600 feet	632	838	Good.
800 feet	990	717	Good.
1,000 feet	437	559	Poor.
1,125 feet	890	1,160	Good.
1,150 feet	758	1,045	Good.
1,250 feet	695	517	Fair.
1,400 feet	586	550	Fair.

Average time to—	*Seconds*
Load	74
Dump	29
Make two turns	51

Table 5.—*Average speed of heavy trucks on short hauls*

[5-ton trucks loaded with 3 cubic yards of blasted rock and earth operating on about 5-percent grades by backing to dump and returning in forward. Trucks in good mechanical condition and hauling road well and systematically maintained. Trucks working with a 1¼-yard shovel]

Length of haul:	*Average round-trip speed—feet per minute*
0 to 50 feet	232
50 to 100 feet	250
100 to 200 feet	274
200 to 300 feet	336
300 to 400 feet	384
400 to 500 feet	435
500 to 600 feet	455

The road speeds for any given vehicle are affected by many factors, the most important of which are the condition of the road surface, grades, and lengths of haul. Road speeds under different conditions are given in tables 3, 4, 6, 7, 8, 9, 10, 11, 12, and 13. For different vehicles, the type, condition, and size are the most important of the factors which affect speed. The extent to which these factors frequently affect the hauling speed is indicated in tables 2, 4, 6, 10, 12, and 14.

Most of the hauling on grading work is done at an average speed of less than 500 feet per minute for trucks, about 300 feet per minute for large tractor-drawn wagons, and about 240 feet per minute for ordinary horse-drawn dump wagons. Average round-trip speeds as high as 900 feet per minute for trucks, 400 feet per minute for tractor-drawn wagons, and 250 feet per minute for horse-drawn wagons are rarely attained, except for short periods and under exceptionally favorable conditions.[1] Tables 3, 7, 10, 12, and 14 show typical average speeds regularly maintained on a number of jobs using various kinds of vehicles.

LARGE CAPACITY HAULING UNITS OFTEN USED

In a summary of studies of power-shovel operation in highway grading compiled in 1927,[2] it was found that the prevailing size of the shovels then in use had a dipper of three-quarters yard capacity. Teams and bottom-dump wagons were by far the most common type of hauling equipment. Trucks were used to some extent, the solid-tire type predominating. Tractor-drawn wagons of 4 or 5 cubic yards capacity were found on comparatively few jobs. At the present time (1933) the 1¼-cubic-yard shovel is found on a majority of jobs and the 1½-yard shovel is observed as frequently as the three-quarter-yard shovel. The team and wagon had practically disappeared while the large truck equipped entirely with pneumatic tires had become the most common type of hauling equipment, followed by the large tractor-drawn wagon, now usually of 6 or 8 cubic yards capacity and generally provided with crawler treads.

In highway grading the hauls for most of the material are usually comparatively short so that road speed is not a prime factor in obtaining production from the hauling units. High speeds are generally impossible because of road conditions. Load-carrying ability, ease of operation, and dependability are more important factors. Recent developments in specialized hauling units have aimed at combining, in a rather low-speed vehicle, large capacity, rapid unloading, easy turning ability, and high mechanical dependability. A number of manufacturers have developed special hauling units designed particularly for operation with the power shovels, elevating graders, and draglines.

[1] For additional data on hauling with teams and wagons, see Public Roads, March 1928.

[2] Power Shovel Operation in Highway Grading, Public Roads, February, March, and April 1928.

TABLE 6.—*Operation characteristics of 7- and 8-yard tractor-drawn wagons*

[Three 1¼-yard shovels on same job. All equipment in good condition. Material, largely sandy earth, some frozen. Heavy trucks used for some very long-haul work. Heaviest grades about 8 percent. Wagons carried an average of 7 cubic yards of pay material per load, trucks carried 4.4 cubic yards]

Hauling unit	Grade	Length of haul	Speed		
			Loaded	Return	Return distance
	Percent	*Feet*	*Feet per minute*	*Feet per minute*	*Feet*
Tractor-drawn wagons	−8	305	270	230	350
Do.	−7	525	273	238	590
		600	327	347	630
Do.	−5	700	320	326	750
Do.	−1	840	334	348	890
Do.	−6	1,025	380	393	1,010
		1,040	388	385	1,070
Heavy trucks	−2	6,400	1,414	1,416	6,400
Do.	+4	6,800	1,275	1,668	6,800

TIME CONSTANT

	Trucks	Wagons
Taking on load ... seconds	135.6	214.6
Turning at fill ... do	50.7	21.3
Dumping load ... do	40.4	20.0
Turning at shovel ... do	43.4	25.7
Waits and delays ... do	41.0	83.0
Total ... do	311.1	364.6

WORKING TIME LOST BY SHOVELS

Class of time loss	Hauling by wagons	Hauling by trucks
Minor time losses of shovels:	*Percent*	*Percent*
Hauling equipment, insufficient supply	4.1	17.3
Hauling equipment, faulty operation	3.1	1.6
Moving shovel within cut	5.0	4.3
Shovel operator	.6	.9
Mechanical repairs and trouble with shovel	2.9	1.9
Sloping	4.3	1.5
Smoothing grade and loading pit	2.7	2.9
Checking grade	.5	.2
Miscellaneous	3.2	3.8
Major mechanical repairs, shovel and cable	2.0	2.9

There are two types of units in general use—those drawn by tractors and those provided with their own power units. Crawler treads are generally used on the tractor-drawn wagons and are also found on the other type. The capacity of these units usually varies from 3 to 10 or even 12 cubic yards. The sizes generally used with power shovels range from 5 to 8 cubic yards. The operation characteristics of tractor-drawn wagons are shown in tables 6, 7, 9, and 14.

Where the grades are easy and the hauling conditions otherwise favorable, two of these wagons are sometimes drawn by one large crawler-tractor. Two wagons are seldom drawn by one tractor where the grades are steep, because of the difficulty of control on the descent. On good or fair roadways and light grades two wagons can be drawn at practically the same speed as one; but it is general practice to shift to one wagon when travel becomes dfficult. (See table 4.)

The observations made are not a conclusive proof that under favorable conditions a tractor can haul two wagons as fast as one since the conditions under which the 1- and 2-wagon operations were studied were not strictly similar. On elevating-grader work on which both 1- and 2-wagon trains were used there was noted a tendency to use two wagons until the hauling road became so bad that 2-wagon trains could not be handled or the haul became so short that a single wagon was more than sufficient. The 1-wagon trains were operated only when the road was poor or when there was no need for speed.

TABLE 7.—*Operating characteristics of heavy trucks and tractor-drawn wagons*

[Two 1¼-yard shovels on one job. All equipment in good condition. Material, earth and blasted limestone. Rates of production, 85 and 110 cubic yards per working hour for the two shovels. Grades light. Average load, 4 cubic yards for heavy trucks and 8 cubic yards for wagons]

Heavy trucks			Tractor-drawn wagons		
Length of haul	Speed		Length of haul	Speed	
	Loaded	Return		Loaded	Return
	Feet per minute	*Feet per minute*		*Feet per minute*	*Feet per minute*
150 feet	240	265	200 feet	235	290
400 feet	296	220	290 feet	279	220
950 feet	966	704	370 feet	310	320

TIME CONSTANT

	Heavy trucks	Tractor-drawn wagons
Taking on load ... seconds	122	239
Turning ... do	8	16
Dump load ... do	18	9
Turning ... do	53	58
Delays and waits ... do	127	237
Total gross time constant ... do	328	559

WORKING TIME LOST BY SHOVEL

Class of time loss	Percent	Percent
Minor time losses:		
Hauling equipment, insufficient supply	3.3	1.0
Hauling equipment, operation	3.0	.6
Moving shovel within cut	9.8	5.5
Shovel operator	1.0	1.2
Mechanical repair or trouble with shovel	1.8	2.2
Clean pit and trim slopes	5.4	6.8
Miscellaneous	6.3	3.6
Major mechanical repairs	4.1	.5

NOTE.—One man did all the sloping.

TABLE 8.—*Time constants and average round-trip speeds of trucks operating with 1¼-yard shovel*

[Hauling road maintained over fills and through cuts with bulldozers equipped with 8-foot blades. On hauls exceeding 1,200 feet a water truck was used to sprinkle the road and keep it firm. When required, 1 or 2 laborers filled holes, ruts, etc. Grades generally about 5 percent]

Operation	Large trucks, 5.7 cubic yards pay load		Smaller trucks, 4 cubic yards pay load	
	Short hauls, no turns	Long hauls, 2 turns	Short hauls, no turns	Long hauls, 2 turns
	Seconds	*Seconds*	*Seconds*	*Seconds*
Load	138	138	120	120
Dump	34	34	38	38
Turn		81		113
Average net time constant	172	253	158	271

AVERAGE ROUND-TRIP SPEEDS, FEET PER MINUTE

Large trucks:	
Downgrade on hauls over 1,250 feet	1,050
Downgrade on hauls between 400 and 800 feet, no turns	262
Upgrade on hauls over 1,500 feet	714
Smaller trucks:	
Downgrade on hauls over 1,250 feet	810
Downgrade on hauls between 400 and 800 feet, no turns	301

TABLE 9.—*Variations in hauling speed with length of haul*

[7-yard crawler-tread wagons with heavy crawler tractors working with 1¼-yard power shovel. Road good, with easy return grades. Average load of pay material, 6.75 cubic yards]

Length of haul	Speed	
	Loaded	Return
	Feet per minute	*Feet per minute*
130 feet	270	269
350 feet	288	279
500 feet	333	314
1,000 feet	354	338

NET TIME CONSTANT

	Seconds
Load	205
Two turns	30
Unload	13
Total	248

TABLE 10.—*Variation of hauling speed with steepness of grade, length of haul, and condition of road surface*

[Heavy trucks carrying 4.0 and 5.7 cubic yards pay material per load, working with 1¼-yard power shovel. Trucks in good condition]

Length of haul	Grade	Speed		Size of load	Condition of road
		Loaded	Return		
	Percent	*Feet per minute*	*Feet per minute*	*Cubic yards*	
150 feet	−6	380	178	5.7	Rough.
150 feet	−6	220	247	4.0	Do.
200 feet	−6	174	315	5.7	Rough and slippery.
350 feet	−9	220	360	4.0	Rough to fair.
1,250 feet	−5	660	662	4.0	Fair.
1,400 feet	−5	680	780	4.0	Good.
1,500 feet	+5	393	720	5.7	Fair.
1,550 feet	+4	405	950	5.7	Do.
1,600 feet	+4	453	1,090	5.7	Good.
1,800 feet	+5	433	1,190	5.7	Fair.
2,000 feet	+5	410	1,200	5.7	Do.
2,700 feet	−5	1,285	847	5.7	Good.
2,700 feet	−5	1,280	708	4.0	Do.
4,000 feet	−5	970	830	4.0	Fair.
4,000 feet	−5	950	900	5.7	Good.

TABLE 11.—*Average speeds on steep grades*

[5-ton trucks backing to dump and returning in forward on hauls of 300 feet with an average of 15-percent grade, one section about 50 feet long was over 22 percent. Trucks in good condition. Road fairly smooth and hard. 1-yard shovel. Studies extended over 3 days]

Day of study	Backing downgrade	Returning upgrade
	Feet per minute	*Feet per minute*
First	347	397
Second	284	342
Third	333	427

AVERAGE TIME CONSTANT

	Seconds
Taking on load	138.7
Dumping load	34.0
Maneuvering on dump	19.0
Total	191.7

[Average grade 12 percent, but one section of 100 feet of 25 percent grade, haul about 350 feet]

Day of study	Backing downgrade	Returning upgrade
	Feet per minute	*Feet per minute*
First	229	370
Second	186	309

TABLE 12.—*Effect of road condition and length of haul on hauling speed of 1½-ton trucks working with power shovel*

[Trucks in fair to good condition. Mostly easy downgrades]

Length of haul	Speed		Condition of road
	Loaded	Return	
	Feet per minute	*Feet per minute*	
150 feet	450	617	Somewhat rough.
170 feet	344	344	Very poor.
275 feet	475	528	Rough.
300 feet	475	617	Do.
320 feet	475	502	Rough and muddy.
325 feet	528	475	Rough.
360 feet	617	800	Mostly fair, some rough.
600 feet	862	818	Fair, easy downgrade.
720 feet	750	660	Fair, with steep downgrade.
1,050 feet	1,190	1,135	Fair to good, some downgrade.

TABLE 13.—*Operating characteristics of heavy trucks working with 1-yard shovel under adverse conditions*

[Mechanical equipment in fair condition. Road fair to poor and very poor. Trucks backed to dump. Average load of pay material, 2.5 cubic yards]

Road condition	Fair	Poor	Very poor	Fair
Length of haul, feet	320	420	530	550
Loaded speed, feet per minute	345	350	250	425
Return speed, do	330	395	360	490
Time constants for various operating conditions:				
Taking on load, seconds	79	78	71	66
Turning, do		35	42	36
Dumping load, do	57	33	27	28
Turning, do		38	20	47
Waits and delays, do	13	41	20	51
Total time constant, do	149	225	180	228

AVERAGE PERCENTAGE OF WORKING TIME LOST

	Percent
Minor time losses of shovel:	
Hauling equipment, insufficient supply	2.9
Hauling equipment, faulty operation	2.3
Moving shovel within cut	2.6
Shovel operator	.4
Mechanical repairs and trouble with shovel	1.1
Checking grade	
Miscellaneous	3.2
Major mechanical repairs, shovel and cable	13.2

MAINTENANCE OF HAULING ROAD IMPROVES EFFICIENCY OF OPERATION

It is not difficult to show that the condition of the road surface has considerable influence on the station-yard cost of hauling, but it is difficult to obtain data as to the reduction in hauling costs which can be obtained by better maintenance of the road surface. Systematic maintenance of the hauling road is not a common practice among grading contractors. Only a few seem to have discovered that it pays to maintain a smooth surface on the hauling road and assign men and equipment specifically to road maintenance. A blade grader is most frequently used but in some cases the bulldozer is used whenever it is not busy on the dump. Systematic maintenance of the hauling roads frequently results in a sufficient increase in operating speed to permit the use of fewer hauling units, more regular operation of the shovel due to the elimination of hauling delays, and greatly reduces the wear and tear on the hauling vehicles.

Tables 5, 8, 13, and 15 are based on time studies on a number of jobs and show variations in road speeds which may be expected with changes in road conditions. These data indicate results which may be expected from adequate maintenance of the hauling road. The advantages of road maintenance are: (1) Faster speed, permitting more loads to be hauled in a given time;

TABLE 14.—*Operating characteristics of 7-yard tractor-drawn wagons*

[Two $1\frac{1}{4}$-yard shovels, working in common excavation. All equipment in good condition. Number of round trips timed, 628. Average load per wagon of pay yardage, 6.75 cubic yards. Grades light]

Length of haul	Speed	
	Loaded	Return
	Feet per minute	*Feet per minute*
270 feet	285	283
325 feet	302	298
400 feet	325	310

AVERAGE TIME CONSTANT

	Seconds
Taking on load	195
Turning, at dump and shovel	31
Dumping	11
Waits and delays	32
Total	269

WORKING TIME LOST BY SHOVELS

Class of time loss	Shovel no. 1	Shovel no. 2
Minor time losses of shovels:	*Percent*	*Percent*
Hauling equipment, insufficient supply	1.3	14.8
Hauling equipment, improper operation	1.2	2.6
Moving shovel within cut	10.0	8.4
Shovel operator	.5	2.0
Mechanical repair and trouble with shovel	1.5	1.7
Sloping	5.2	3.6
Smoothing grade and loading pit	2.7	5.5
Checking grade		.3
Miscellaneous	.7	3.5
Major mechanical repairs to shovel and cable	4.2	3.2

When the average round-trip wagon speed was 283 feet per minute for drawing 1-wagon trains, this was reduced to 259 feet per second on changing to 2-wagon trains. The loading time was increased from 195 seconds to 405 seconds.

TABLE 15.—*Operating speed of heavy trucks on steep grades*

[Trucks operating with $1\frac{1}{2}$-yard shovel and carrying average load of 3.5 cubic yards of pay material. All equipment in good condition. Hauling road which had one or more sharp curves maintained fairly smooth]

Grade	Length of haul	Loaded	Return
	Feet	*Feet per minute*	*Feet per minute*
Minus 25 percent	500	310	283
Do	550	305	290
Minus 20 percent	650	330	300
Do	900	350	345
Minus 6 percent	700	550	565

TIME CONSTANT

	Seconds
Taking on load	89
Turning	34
Dumping load	29
Turning	30
Waits and delays	84
Total	266

WORKING TIME LOST BY SHOVEL

	Percent
Minor time losses of shovel:	
Hauling equipment, insufficient supply	4.3
Hauling equipment, faulty operation	5.3
Moving shovel within cut	2.4
Shovel operator	.4
Mechanical repairs and trouble with shovel	1.8
Sloping	1.1
Smoothing grade and loading pit	.1
Miscellaneous	7.8
Major mechanical repairs, shovel and cable	.2

(2) larger loads; (3) greater regularity in operation, thus reducing delays at the shovel; and (4) less wear and tear on the hauling equipment.

Figure 1 shows graphically the average hauling speeds attained before and after a road was smoothed and shaped with a blade grader. The grade which averaged about 4 percent was quite rough before the blading and the average speed over it was only 630 feet per minute for loaded vehicles and 658 feet per minute for unloaded vehicles in returning up the grade. As a result of work with a blade grader the speed of the loaded vehicles was increased to 1,050 feet per minute and the speed of the unloaded vehicles was increased to 965 feet per minute. The improvement of the earth road resulted in an increase of 66.7 percent in the speed of the loaded vehicles and an increase of 47 percent in the return speed of the empty vehicles up the grade. While this is only one example and involved only heavy trucks carrying $3\frac{1}{2}$ cubic yards of material, it is believed that conditions were typical of those to be found on many projects. Sprinkling the roadway in very dry weather has sometimes been found advantageous.

Aside from rough or soft yielding road surfaces, the chief deterrent to speed is steep grades. Sometimes all of these conditions are combined to form exceptionally bad hauling conditions. The effect of ascending grades is to gradually decrease the hauling speed at a rate somewhat faster than the increase in grade, as successive points are reached at which shifts must be made to lower gear ratios, until finally a point is reached at which the vehicle can no longer haul the load. The only recourse then is to reduce the load. In highway grading work, however, the steepest grades are almost invariably descending grades for the loaded vehicle. The limiting grade is therefore usually fixed by the climbing ability of the unloaded vehicle while both the size of the load and the speed of the loaded vehicle on the descent are largely fixed by safety considerations rather than the hauling ability of the vehicle. The extent to which grades reduce actual hauling speed is indicated in tables 4, 6, 10, 15, 16, and 17. Figures 1 and 2 illustrate the way in which the rate of speed varies on a grade.

Soft or yielding road surfaces have much the same effect in reducing the speed and load-carrying capacity of the hauling vehicles as a grade. As the road surface

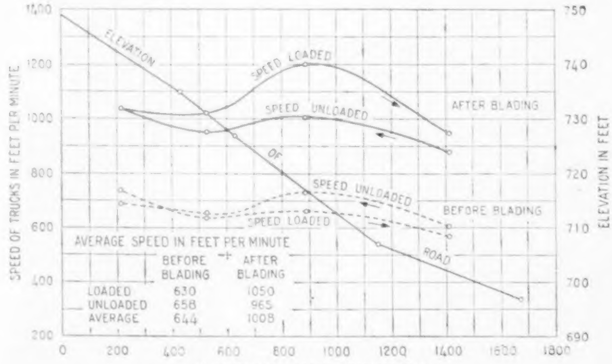

FIGURE 1.—SPEEDS AT WHICH 5-TON SOLID-TIRED TRUCKS IN GOOD CONDITION OPERATED BEFORE AND AFTER MAINTENANCE WITH A BLADE GRADER. CURVES SHOW SPEEDS AT VARIOUS POINTS ALONG 2- TO 4-PERCENT GRADE.

TABLE 16.—*Speed of truck operation on long, moderate grades*

[Hauling excavation from 1¼-yard shovel, 5-ton trucks, good condition. Pay load, 3.8 cubic yards. Long 6-percent grade, generally fair condition]

Length of haul	Loaded	Return
	Feet per minute	*Feet per minute*
800 feet	800	643
1,000 feet	870	828
1,100 feet [1]	335	387
1,100 feet	1,055	970
1,300 feet [2]	828	1,100
2,000 feet [3]	1,020	950

[1] Effect of narrow road which prevented easy passing of loaded and empty trucks.
[2] Road somewhat slippery, requiring caution on downgrade.
[3] Part of road somewhat spongy.

AVERAGE TIME CONSTANT

	Seconds
Load	110
Turn and back at dump	53
Dump load	11
Turn and spot at shovel	31
Waits and delays	40
Total	245

TABLE 17.—*Effect of rough road surface on increase in speed with increase in distance*

[Trucks hauling 2 cubic-yard loads of blasted rock down rough 5 percent grade. Trucks in fair to good condition; road surface very rough entire distance]

Length of haul	Speed	
	Loaded	Return
	Feet per minute	*Feet per minute*
320 feet	370	317
600 feet	370	387
1,000 feet	440	395
1,100 feet	457	397
1,250 feet	440	405

gives or depresses under the wheels of the moving vehicle there is the equivalent of an obstruction in front of the wheels which is effective in reducing speed. In very soft ground loads must be drastically reduced or hauling discontinued until the road becomes more stable. Hauling speeds are sometimes seriously reduced by the slipperiness of the road surface. Some gumbo and clay soils become extremely slippery and difficult to travel over when wet only on the surface.

DETERMINATION OF REQUIRED NUMBER OF HAULING UNITS NOT A DIFFICULT PROBLEM

Attention has been called to the practical difficulties in keeping the shovel supplied with hauling units. Some of these difficulties are inherent in the nature of the work. Others can be ascribed to the contractors. On some jobs, however, the extent and frequency of variations in length of haul are largely due to failure of the designing engineer to appreciate the extent to which such fluctuations affect the cost of performing the work. The hauls on a job for which the average haul is 500 feet may be so distributed that hauling equipment sufficient to haul all of the material 1,000 feet must be provided. Even under favorable conditions this extra hauling equipment will probably add 3 or 4 cents per cubic yard to the unit cost of the job without adding any compensating value to the completed work.

It is believed that designers can profitably devote more attention to reducing variations in haul distances to permit more effective use of hauling equipment.

The length of haul is usually short—seldom more than 600 or 800 feet as the average haul for most of

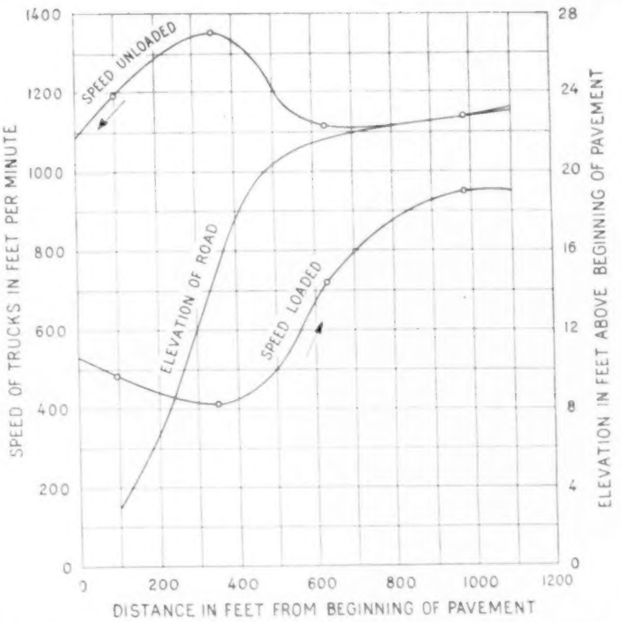

FIGURE 2.—SPEED OF 5-TON SOLID-TIRED TRUCKS HAULING OVER OLD BITUMINOUS MACADAM SURFACE. SHOVEL LOCATED ABOUT 100 FEET FROM HIGHWAY.

the yardage. The difficulty is that the average haul is quite different from the actual hauls the contractor must make to place the materials in conformity with the requirements. The haul distance may readily vary from practically zero to 2,000 or 3,000 feet and in extreme cases to 4,000 or 5,000 feet for a relatively small part of the material.

These varying lengths of haul, in which the rate of variation is seldom uniform, cause difficulties in maintaining a correct number of hauling units not found in other lines of transportation. As the length of haul changes, the number of hauling units should be increased or decreased if perfect balance is to be maintained. In practice, this is usually impossible. The changes in haul lengths are too frequent to make this practical, and the number of hauling units maintained on the job is usually almost constant from day to day and frequently for the whole job. This requires the selection of such number of vehicles that when the hauls are long the supply will be insufficient and the shovel will lose time waiting for vehicles, while on short hauls the supply will be too large and the hauling vehicles will lose time waiting for the shovel. When this arrangement is necessary, the number of vehicles selected should be such that the job can be completed at a minimum cost. How this number can be determined will be shown later.

Determination of the number of hauling units of given size and kind required for a given set of operating conditions is not difficult. Values for the necessary factors can be determined readily by timing operations with a stop watch. Only factors which can readily be determined and checked from time to time need be used in the following method: Let

S = average round-trip speed of hauling unit in feet per minute exclusive of all stops, turning, switching, etc.

T = total time constant in minutes; that is, the sum of the average time required each round trip to take on the load, dump it, turn and maneuver both at the dump and shovel, and all regular stops and delays.

A, Two 5-Cubic-Yard Wagons Drawn by a Tractor; B, Truck Designed for Easy Backing; C, Truck Dumping About 4½ Cubic Yards of Material.

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t = time in minutes required to take on load, or longest regular stop or delay if this exceeds the loading time.

L = length of haul in feet.

N = number of vehicles required to just keep shovel in continuous operation for any haul, L.

A = rental value of hauling vehicle, including driver and operating cost, in cents per hour of working time.

W = average pay load, in cubic yards, carried by vehicle.

C = cost of hauling in cents per cubic-yard station.

K = cost in cents per cubic yard for hauling the material a distance L.

Q = number of loads hauled per hour by one vehicle.

Then

$$N=\frac{2L}{St}+\frac{T}{t} \tag{2}$$

$$Q=\frac{60S}{2L+ST} \tag{3}$$

$$K=\frac{A}{60W}\left(\frac{2L}{S}+T\right) \tag{4}$$

$$C=\frac{5A}{3W}\left(\frac{2}{S}+\frac{T}{L}\right) \tag{5}$$

Formula 2 gives the number of vehicles required to just keep the shovel in continuous operation when it is working at the rate indicated by the factor t, which is the average time required to load each vehicle. Care must be taken, however, that the operation of the hauling units is such that no regular stop exceeding t is permitted; otherwise this stop, and not the loading rate of the shovel, becomes the pacemaker. As an example: With wagons having an average round-trip speed of 400 feet per minute, a time constant, T, of 5 minutes, and which can be loaded by the shovel in 2½ minutes, the number of hauling units required for a haul of 1,000 feet is determined by formula 2 as follows:

$$N=\frac{2\times 1000}{400\times 2.5}+\frac{5}{2.5}=\frac{2000}{1000}+2=4$$

Four wagons will thus be required under these conditions to maintain full shovel production. An additional vehicle must be added or taken off whenever the haul changes by the distance $\frac{St}{2}$, in this case

$$\frac{400\times 2.5}{2}=500 \text{ feet.}$$

CONDITIONS REQUIRING ADDITIONAL UNITS ANALYZED

The addition of another vehicle at the first indication of insufficient hauling equipment is not economical. This is especially true when vehicles of large capacity are used. To examine this question, let

D = total rental or operating cost to the contractor per hour of working time of vehicle to be added.

G = total cost to the contractor per hour of working time of his working force and equipment, including dump operations, before vehicle is added.

H = the number of minutes per hour which shovel can afford to wait for hauling units before this waiting becomes more expensive than adding another hauling vehicle.

Then

$$H=\frac{60D}{G+D} \tag{6}$$

HAULING UNDER ADVERSE CONDITIONS.

A contractor who is using trucks costing $3 per hour of working time notices that because of the increasing haul distance his shovel is spending time waiting for hauling units. The operating cost of the equipment and force he now has, including shovel, hauling and dump operations, amounts to $20 per working hour. How much time can he afford to let the shovel lose before it will be economical to provide another vehicle? From the above (formula 6), we have $H=\frac{60\times 3}{20+3}=7.8$. He can therefore afford to lose no more than 7.8 minutes an hour before the value of the losses in reduced production will exceed the cost of the additional vehicle.

IN HEAVY WORK THE BULLDOZER IS ESSENTIAL TO ORDERLY DUMP OPERATION.

When the shovel is losing 7.8 minutes an hour in waiting for trucks, then the addition of another truck at $3 an hour will neither increase nor decrease the unit cost of handling the material at this haul. The extra truck should be added whenever this length of haul is exceeded. By permitting the shovel to work continuously, the added truck will permit handling all the material with hauls longer than this at less cost than would be possible without the added truck.

The only factor to be watched in order to know when it becomes economical to add another hauling unit is the time lost by the shovel in waiting for vehicles. Consequently, no contractor should be without a stop watch, or fail to make regular use of it. If, however, a determination of the time lost by the shovel while waiting for hauling units is impractical, the length of haul at which another hauling unit should be added can be determined from the following formula in which all the terms have the same significance as previously given.

$$L'=\frac{S'}{2}\left(N-\frac{T}{t}+\frac{ND}{G}\right) \tag{7}$$

Here, L' is the length of haul at which it becomes economical to add another vehicle.

Large-capacity hauling units are frequently used with the power shovel, and the efficiency with which they can be operated is important. Under ordinary field conditions, the vehicles cannot maintain perfect operation. Drivers become careless or inattentive and the vehicles require attention from time to time.

Aside from vehicle delays which arise from having too many vehicles, there will be delays imposed by the shovel and delays due to the trucks themselves or their operators. On a poorly managed job the total of these delays may be very large, and even on well-managed jobs they may consume from one-third to one-half of the total available working time of the trucks.

Table 18 gives the time losses on a fairly well-managed job for two kinds of trucks operating with different shovels. All the trucks were in good to fair condition. The 3½-ton trucks operating with the first shovel carried an average load of 3 cubic yards of pay material while the 5-ton trucks operating with the second shovel carried average loads of 4½ cubic yards of pay material. The average haul was about 1,000 feet for the first and about 700 feet for the second. Grades were frequently steep but the road, pit, and dump were maintained in better than average condition. The studies cover a total of 1,467 truck-hours and 1,202 truck-hours, respectively.

Table 18 indicates the necessity of taking time losses into account in determining the time constant to be used in formula 2 for determining the number of hauling units required. The ordinary shovel delays are, of course, reflected in the average time required to take on load. All regularly occuring delays to the hauling equipment which cannot be eliminated must be added to the time constant, otherwise the indicated number of vehicles will be insufficient. In determining the truck delays to be included in the time constant, care should be taken to exclude all delays resulting from having too many vehicles. Regular waits at the shovel indicate an oversupply, but regular delays at the dump are an indication of improper dump operation. If the trouble cannot be removed these delays at the dump must be included in the time constant.

METHOD OF DETERMINING REQUIRED NUMBER OF HAULING UNITS ILLUSTRATED

The number of hauling units to be maintained with the shovel in order to complete the job at the lowest possible cost deserves more attention than this problem usually receives. The heavy trucks or tractor-drawn wagons generally used are usually considered to cost from $2 to $3 per hour, sometimes more. They are too expensive to warrant the use of more than are necessary. On the other hand, a shortage of only one vehicle on a moderate haul may readily reduce shovel production by 20 to 30 percent. The number of hauling units which the contractor maintains on the job therefore bears a very definite relation to the profits which the job may be made to yield.

TABLE 18.—*Percentage of available working time lost by trucks working with power shovels in well-blasted rock, shale and earth, and general data on operation*

[All trucks in good to fair condition]

Cause of delays to trucks	Working time lost by trucks working with—	
	Shovel 1	Shovel 2
Major stops each of 15 or more minutes in duration:	*Percent*	*Percent*
Shovel casting	0.3	2.8
Shovel down, trucks waiting	15.1	12.5
Truck down, adjustments, repairs, tires, etc	13.2	5.1
Too many trucks on job	6.7	11.9
Total major time loss	35.3	32.3
Minor stops each less than 15 minutes in duration:		
Operating delays on road and at dump	2.3	2.6
Waits to get under shovel	14.6	11.1
Total minor delays	16.9	13.7
Actual productive working time of trucks	47.8	54.0
General data:		
Total available trucks, hours	1,467.0	1,202.5
Average pay yardage per load, cubic yards	3.0	4.5
Average length of haul, feet	970	675
Average round-trip speed, feet per minute	520	500
Average net loading time, minutes	2.5	3.1
Total pay yardage hauled, cubic yards	23,444	31,090

A SMALL TRUCK BODY REQUIRES CAREFUL SPOTTING OF THE DIPPER AND INCREASES DUMPING TIME.

The number of hauling units required for a particular set of operating conditions and length of haul can be readily determined by means of formula 2. This, however, offers no direct solution of the problem of the number of hauling units to be brought on a job where conditions permit few, if any, changes to be made during the progress of the work. For this, a more detailed procedure is necessary.

To analyze this problem the quantities which must be hauled each given distance are first tabulated. These quantities and distances can most readily be taken from a mass diagram [3] and are tabulated as shown in table 19. The quantities as taken from the mass diagram for each haul are summarized and entered in the first column of the table, with the corresponding haul distance given in the second column. On the project analyzed much material was to be hauled less than 500 feet, but the shorter hauls were all sum-

[3] For a brief discussion of the mass diagram and a method of taking off the quantities to be hauled any given distance, see PUBLIC ROADS, March 1928, pp. 18 and 19.

marized under this distance since it was clear that any possible minimum equipment for this job would be more than that required to keep the shovel at full production on a 500-foot haul. To further subdivide this short-haul material would only be useless labor.

TABLE 19.—*Determination of most economical number of trucks to use on a given job*

Quantities (cubic yards)[1]	Length of haul	Shovel working at full production rate		Time to complete job with—			
		Hours to complete given yardage	Number of trucks required	2 trucks	3 trucks	4 trucks	5 trucks
	Feet			*Hours*	*Hours*	*Hours*	*Hours*
14,400	500	18.00	3.00	27.00	18.00	18.00	18.00
10,800	600	13.50	3.07	20.75	13.83	13.50	13.50
7,200	700	6.00	3.24	14.58	9.72	9.00	9.00
10,800	800	13.50	3.42	23.10	15.40	13.50	13.50
15,760	900	19.70	3.44	33.90	22.58	19.70	19.70
7,200	1,100	9.00	3.76	16.92	11.28	9.00	9.00
18,400	1,500	23.00	4.00	46.00	30.70	23.00	23.00
12,800	3,000	16.00	4.67	37.40	25.00	18.70	16.00
10,600	4,000	13.25	5.55	36.80	24.50	18.41	14.70
Hours required to complete job		134.95		256.45	171.01	142.81	136.40
Estimated cost of complete job, dollars				4,103.20	3,249.19	3,141.82	3,410.00

[1] Total, 107,960 cubic yards.

This example is based on a 1¼-yard shovel operating in common excavation at a rate of 80 cubic yards per working hour. Cost of equipment and personnel on shovel, dump, and maintaining hauling road estimated at $10 per working hour. Rental value of truck and driver, $3 per working hour. For truck operation on the job the following values were used: $T=5.0$ minutes; $t=2.5$ minutes, while since the grades were not bad and a patrol grader was available for maintenance, S was taken as 400 feet per minute for all hauls to and including 500 feet; 450 feet per minute for the hauls above 800 feet to and including 1,100 feet; 600 feet per minute for all hauls of 3,000 feet or more.

If trucks could be employed and discharged in conformity with the fluctuations in the length of haul, the cost of completing the job could be reduced to about $2,900.

BULLDOZERS CAN OFTEN BE USED IN OPENING THE CUT AND PREPARING A HAULING ROAD AHEAD OF THE SHOVEL.

In the third column was entered the number of hours estimated as required to move the quantities shown in the first column with a full supply of hauling equipment; in other words, the time required for the shovel to handle these quantities when working at full production. In estimating the production rate for the shovel the contractor should consider his past experience and all available evidence in regard to the character of the material and the probable conditions under which the work will be performed. If different classes of material resulting in different production rates are involved, such as common excavation, loose rock, and solid rock, the known or probable quantities of each should be entered in column 1 for each haul distance. This will result in a more reliable estimate of the time required to complete the work at each haul distance.

In the fourth column was entered opposite each haul distance and corresponding quantity the number of hauling units which would probably be necessary to maintain the shovel at full production at this haul distance. Numbers of trucks are computed with formula 2, using values for T, t, and S based on experience and judgment. The indicated number of vehicles will, in general, be a mixed number and should be entered to at least one decimal place. Two places are used in this example.

There was then entered in the following columns the time in hours required to complete each set of quantities with the number of trucks indicated. Whenever the number of hauling units is equal to or greater than that required to maintain the shovel at full production, the time required to perform the work will be determined by the shovel. When the number of hauling units is less than that required to maintain the shovel at full production, the time will be determined by the hauling equipment. This new or increased time figure will have the same ratio to the time required for completion, as given in column 3, as the required number of hauling units, as given in column 4, has to the number of hauling units which is actually to be used. The computations are simple and can be made quickly on the slide rule. The column totals give the number of hours that will be required to complete the job, when hauling equipment is supplied to the shovel exactly as needed (column 3), and when each of the assumed hauling supplies is employed continuously with the shovel until the job is completed. In this example all hauling units have been assumed to be of the same size and speed. If vehicles of different sizes and speeds are to be used the computations are more extended.

The final step in making this table was to compute the operating cost when each of the assumed hauling supplies was used for the corresponding period required to complete the job. In accordance with general experience it was assumed that the hourly rental value of the shovel and the equipment on the dump would be practically constant, regardless of the average rate of production within the limits of this particular job. The same assumption was made with regard to the personnel employed with the shovel and on the dump. The total cost per operating hour of the equipment and personnel at the shovel and dump was then estimated for the conditions which would most probably exist on the proposed job. To this was added the estimated hourly or daily rental value of the given number of hauling units with their drivers. In computing table

19, the estimated operating cost of shovel and dump was assumed for purposes of illustration at $10 per hour. The hauling equipment was assumed as heavy trucks at $3 per hour with driver. The hourly cost of operation is therefore $16 when using only 2 trucks and $25 per hour when using 5 trucks.

Completing the indicated multiplications, we find that it would cost the contractor $3,141 to complete the job with 4 trucks. Any other number of trucks, if kept out on the job throughout, would result in a higher cost. However, if trucks could have been employed and paid for only during such time as they were needed to keep the shovel at full capacity, the cost of completing the job would have been but slightly more than $2,900. The variable haul distances increased the cost of the earthwork on this job by at least $240, or nearly 8 percent—an item worth consideration by both the contractor and the designing engineer.

Occasionally the extreme hauls are localized to a certain portion of the job. In such cases the project should be divided into sections and a solution made for each. Having determined the most economical number of trucks for each section, the contractor can plan to increase or decrease the number of hauling units by the determined number when the proper points are reached.

STANDARDIZATION OF EQUIPMENT AIDS EFFICIENCY

The use of a variety of different kinds of equipment has a tendency to increase time losses and decrease production. Equipment is subjected to extremely hard usage and mechanical troubles invariably occur from time to time. It is much cheaper and less difficult to keep an adequate supply of spare parts on hand when the equipment is closely standardized than when a variety of different kinds and sizes of equipment is used. Standardization of hauling units permits interchange of parts and one line of spare parts will suffice for all the hauling equipment. If more than one shovel is employed, there is the same advantage in having them alike. This will permit not only the carrying of a smaller investment in repair parts but operators can be shifted from one piece of equipment to another without impairment of efficiency. Repair men will become more expert in making repairs as well as in diagnosing trouble and in the routine care of the equipment.

Equipment earns no profit except when working. Anything which helps to keep and continue the equipment in working order is therefore of definite value to the contractor. Standardization of equipment so as to permit a wide interchangeability of parts usually requires no outlay and only a little definite planning and forethought, and should be embraced by all contractors to whatever extent their lines of work will permit.

The most striking fact brought out by these studies is that power-shovel grading work is more a problem of transportation than of excavation. If the hauling equipment is insufficient or is not operated with precision, the shovel is handicapped, production is relatively low, and unit costs are high. On the other hand, if too many hauling units are used, unit production costs are unnecessarily increased while the problem of proper operation of the hauling units still remains. Therefore control and operation of the hauling equipment requires the constant and most painstaking attention of the management.

This attention to the hauling should not be given at the expense of an almost equally vigilant attention to all other parts of the job. The contractor can never afford to forget that the shovel is the key item of equipment. It must be constantly maintained in proper condition and operated with a high degree of skill and judgment. Operations on the dump must not be allowed to hamper or interfere with the rapid and orderly movement of the hauling units. If the ground is too hard to dig readily, drilling and blasting must also be carried on with efficiency and dispatch.

But, even all this is not sufficient. Real efficiency is attained only when all operations are performed efficiently and at the same time so coordinated and synchronized that all of these several operations proceed methodically and without interference as a definite part of one single process. To attain such a degree of efficiency in power-shovel grading work requires the constant attention of managerial ability of the highest order. However, the rewards to be gained from such management are such that no grading contractor can afford to be without it.

MOTOR-VEHICLE REGISTRATIONS, 1933 [1]

[Compiled from reports of State authorities]

State	1933 registered motor vehicles—private and commercial [2]					Other registered vehicles		Tax-exempt official motor vehicles and motorcycles [3]			Licenses, permits, and certificates of title			1932 total registered motor cars, busses, and trucks (revised) [11]	Year's change in motor vehicle registration		State
	Grand total registered motor cars, busses, and trucks	Total passenger vehicles, cars, and busses [4]	Private passenger cars [5]	Public passenger vehicles [6]	Total freight vehicles, trucks, and tractors [4]	Trailers and semi-trailers [7]	Motor-cycles	United States cars, etc. [8]	State and local vehicles [9]	Motor-cycles (official)	Dealer's licenses	Operators and chauffeurs permits	Certificates of title [10]		Number	Percent	
Alabama	206,361	176,523	175,483	1,040	29,838	4,007	551	403	975	16	1,765	1,285	(12)	225,846	−19,485	−8.63	Alabama.
Arizona	89,496	74,927	-	-	14,569	1,989	293	672	1,541	23	145	10,312	38,003	94,935	−5,439	−5.73	Arizona.
Arkansas	188,242	155,262	-	-	32,980	6,887	356	297	[11] 450	-	[11] 306	3,346	-	136,583	51,659	37.82	Arkansas.
California	1,958,807	1,738,720	-	-	220,087	69,987	8,134	2,502	34,565	924	3,043	590,047	-	1,974,932	−16,125	−.82	California.
Colorado	266,491	239,058	-	-	27,433	832	788	521	(13)	(13)	[11] 527	17,262	96,243	286,211	−19,720	−6.89	Colorado.
Connecticut	314,751	262,187	-	-	52,564	1,816	1,985	733	2,910	240	2,232	413,538	(12)	321,580	−6,829	−2.12	Connecticut.
Delaware	51,099	[14] 42,614	-	-	[14] 8,485	912	318	149	493	91	512	69,149	23,345	52,341	−1,242	−2.37	Delaware.
Florida	279,265	234,246	-	-	45,019	9,567	834	596	3,365	-	2,802	2,731	96,851	286,021	−6,756	−2.36	Florida.
Georgia	330,147	278,935	-	-	51,212	5,836	956	698	(13)	(13)	1,883	5,091	1,026	287,716	42,431	14.75	Georgia.
Idaho	96,255	81,371	81,282	89	14,884	10,039	286	263	1,156	5	237	254	(15)	96,039	216	.22	Idaho.
Illinois	1,463,050	[14] 1,276,864	-	-	[14] 186,186	9,228	4,959	1,810	(15)	(15)	2,922	66,559	-	1,489,147	−26,097	−1.75	Illinois.
Indiana	770,071	653,710	652,800	910	116,361	27,996	2,561	589	(13)	(13)	2,265	894,939	251,057	797,126	−27,055	−3.39	Indiana.
Iowa	632,292	562,802	-	-	69,490	2,416	1,671	424	4,389	48	[11] 1,565	72,732	-	682,905	−50,613	−7.41	Iowa.
Kansas	517,987	[14] 445,583	-	-	[14] 72,404	3,847	709	338	[11] 4,000	-	1,153	43,934	-	504,784	13,203	2.62	Kansas.
Kentucky	294,547	262,436	261,006	[17] 1,430	[18] 32,111	(18)	822	466	2,914	67	678	8,077	(12)	291,309	3,238	1.11	Kentucky.
Louisiana	232,688	190,681	189,058	1,623	42,007	6,957	712	450	3,698	66	333	21,279	-	238,877	−6,189	−2.59	Louisiana.
Maine	168,173	132,902	131,765	[19] 1,137	35,271	5,893	1,001	229	1,960	92	1,106	215,553	(12)	171,424	−3,251	−1.90	Maine.
Maryland	313,274	278,546	-	-	34,728	1,383	1,485	1,018	[11] 1,400	-	5,228	71,732	224,362	322,106	−8,832	−2.74	Maryland.
Massachusetts	789,788	689,934	686,249	3,685	99,854	525	948	1,301	2,800	[11] 500	2,753	1,022,662	(12)	801,317	−11,529	−1.44	Massachusetts.
Michigan	1,077,209	[14] 955,570	-	-	[14] 121,639	78,998	2,914	866	(13)	-	1,384	266,391	418,226	1,136,224	−59,015	−5.19	Michigan.
Minnesota	679,243	580,113	579,908	205	99,130	19,648	1,687	644	3,109	78	872	48,867	1,140	682,953	−3,710	−.54	Minnesota.
Mississippi	164,688	131,764	-	-	32,924	850	199	262	[11] 2,000	-	[11] 428	-	-	153,741	10,947	7.12	Mississippi.
Missouri	698,362	[14] 594,567	-	-	[14] 103,795	13,110	1,492	842	2,252	21	1,622	38,399	265,600	717,460	−19,098	−2.66	Missouri.
Montana	110,245	[14] 82,765	-	-	[14] 27,480	483	272	631	[11] 1,300	-	433	223	12,324	109,203	1,042	.95	Montana.
Nebraska	390,651	336,704	336,437	267	53,947	14,727	988	278	1,488	-	[11] 3,795	472,324	11,522	374,849	15,802	4.22	Nebraska.
Nevada	28,324	22,397	-	-	5,927	631	92	116	551	-	70	-	-	31,378	−3,054	−9.73	Nevada.
New Hampshire	107,631	87,759	87,492	[20] 267	19,872	1,922	1,102	231	61	2	[11] 416	[11] 129,750	-	105,215	2,416	2.30	New Hampshire.
New Jersey	845,734	723,506	714,358	[21] 9,148	122,228	3,162	5,268	872	8,901	787	2,427	1,043,185	[22] 200,000	854,782	−9,048	−1.06	New Jersey.
New Mexico	76,643	61,353	61,065	288	15,290	983	263	410	839	-	84	-	-	76,872	−229	−.30	New Mexico.
New York	2,240,757	1,942,249	1,905,733	[23] 36,516	[24] 298,508	13,545	12,723	3,048	21,609	1,063	4,955	3,201,357	-	2,249,509	−8,752	−.39	New York.
North Carolina	382,308	332,648	327,816	4,832	49,660	13,012	1,151	563	8,878	-	[11] 573	-	193,192	376,326	5,982	1.59	North Carolina.
North Dakota	153,889	[14] 128,547	-	-	[14] 25,342	143	204	181	453	-	283	-	31,373	153,232	657	.43	North Dakota.
Ohio	1,554,314	[14] 1,396,125	-	-	[14] 158,189	61,156	5,940	1,664	14,074	353	3,131	26,240	-	1,589,322	−35,008	−2.20	Ohio.
Oklahoma	451,712	385,755	-	-	65,957	4,184	[11] 700	742	[11] 2,000	-	[11] 1,200	-	-	415,644	36,068	8.68	Oklahoma.
Oregon [25]	239,410	207,202	[26] 206,502	[27] 700	[28] 32,208	[29] 1,750	1,421	538	3,204	-	322	106,503	84,398	258,762	−19,352	−7.48	Oregon.
Pennsylvania	1,635,019	1,415,522	1,409,708	[30] 5,814	219,497	10,139	11,436	1,816	15,589	1,315	23,718	2,112,195	881,133	1,665,418	−30,399	−1.83	Pennsylvania.
Rhode Island	136,261	118,296	117,161	[31] 1,135	17,965	92	882	189	1,141	72	273	170,509	-	133,408	2,853	2.14	Rhode Island.
South Carolina [32]	162,735	144,940	144,794	146	17,795	1,764	444	290	2,721	157	[11] 426	259,535	69,464	176,370	−13,635	−7.73	South Carolina.
South Dakota	169,249	146,485	146,408	77	22,764	9,693	287	342	922	10	[11] 364	-	28,000	162,096	7,153	4.41	South Dakota.
Tennessee	312,180	278,332	276,762	[33] 1,570	33,848	2,982	1,064	415	2,500	-	[11] 398	-	-	298,713	13,467	4.51	Tennessee.
Texas	1,201,762	1,013,086	1,012,415	671	188,676	36,073	3,355	1,729	8,530	232	[11] 2,440	[11] 56,730	-	1,197,443	4,319	.36	Texas.
Utah	100,362	84,014	-	-	16,348	457	447	428	900	-	147	30,283	9,028	97,234	3,128	3.22	Utah.
Vermont	73,576	65,652	65,531	121	7,924	683	553	138	[11] 400	-	272	92,675	-	77,475	−3,899	−5.03	Vermont.
Virginia	344,704	288,048	285,497	2,551	56,656	1,845	1,756	1,366	4,295	61	[11] 2,300	[11] 12,077	144,314	376,512	−31,808	−8.45	Virginia.
Washington	427,406	364,858	363,706	[34] 1,152	62,548	4,849	1,629	1,220	6,786	175	966	410,860	240,838	445,314	−17,908	−4.02	Washington.
West Virginia	226,985	193,570	192,393	[35] 1,177	33,415	2,094	1,164	162	3,064	90	5,645	69,218	96,305	225,137	1,848	.82	West Virginia.
Wisconsin	670,797	566,450	566,045	405	104,347	2,565	2,256	514	5,817	297	1,574	60,517	14,941	695,953	−25,156	−3.61	Wisconsin.
Wyoming	52,560	41,917	-	-	10,643	[11] 20	121	332	473	-	278	-	-	56,209	−3,649	−6.49	Wyoming.
District of Columbia	149,790	133,048	125,373	[36] 7,675	16,742	1,112	808	1,854	2,789	110	2,253	76,444	70,677	161,176	−11,386	−7.06	District of Columbia.
Total	23,827,290	20,600,543	(37)	(37)	3,226,747	472,789	91,987	[8] 36,475	193,262	6,895	94,504	12,214,764	3,503,362	24,115,129	−287,839	−1.19	Total.

[1] This table lists only the number of registrations, licenses, and permits.

[2] The first 5 columns show regularly registered motor cars, busses, and trucks, with reregistrations, nonresident registrations, tax-exempt vehicles, etc., eliminated whenever possible.

[3] These official cars are exempted from paying regular registration fees and are excluded from "registered motor vehicles."

[4] In certain States noted below busses are registered as trucks and are included in the truck registration.

[5] Data shown here only where private passenger cars can be segregated from public passenger vehicles.

[6] Satisfactory data have not been obtained from several States. These data may include such vehicles for hire as taxis, U-Drive-It cars, livery cars, ambulances, hearses, and busses (not tax-exempt), where the information is obtainable. In most cases only busses are reported in this column, but in certain States the number of taxis, etc., are reported and are so noted.

[7] No segregation is made as between freight and passenger trailers.

[8] As reported by the Budget Bureau in 1931. The total includes 333 cars "at-large" not assignable to any State.

[9] Official cars which are exempt from full fees.

[10] Both original certificates and transfers are shown.

[11] Revised figures resulting from the 1932 special survey.

[12] None issued.

[13] Included with registered motor vehicles as full fees are paid.

[14] Busses reported as registered with trucks and are so included.

[15] No record of number issued as no charge is made.

[16] Nominal fee paid on official vehicles and they are included with registered motor vehicles.

[17] Includes 1,024 taxis.

[18] Trailers included with trucks.

[19] Includes 1,016 taxis.

[20] Includes 6 snowmobiles.

[21] Includes 4,286 taxis.

[22] Number of title papers recorded from bills of sale; no certificates issued.

[23] Includes approximately 30,516 taxis.

[24] Includes 7,720 suburban convertible cars.

[25] Data covers registration year ending June 30, 1933.

[26] Excludes 11,700 light-delivery cars as estimated from data of previous year and reported by State as passenger cars.

[27] Includes 309 taxis.

[28] Includes 11,700 light-delivery cars, and excludes 1,750 trailers (estimated) reported with trucks by State.

[29] Approximate number estimated from data for previous year.

[30] Busses only reported; approximately 3,000 taxis not reported with public passenger vehicles.

[31] Includes 632 taxis.

[32] Data covers only 10 months as registration year was changed from calendar year to year ending Oct. 31.

[33] Includes 1,220 taxis.

[34] Includes 581 taxis.

[35] Includes 692 taxis.

[36] Includes 6,879 taxis.

[37] Total not recorded, as only about one-half of States reported segregated data under public passenger cars.

STATE MOTOR VEHICLE REGISTRATION FEES, 1933

[And miscellaneous receipts (excluding special for-hire carrier taxes and fees)] [1]

State	Total receipts registration fees, and miscellaneous receipts	Motor vehicle registration fees: Total motor vehicle registration fees [2]	Passenger vehicles: Total [3]	Passenger vehicles: Private cars [4]	Passenger vehicles: Public vehicles [5]	Total trucks and tractor trucks [6]	Registration fees, other vehicles: Trailers and semi-trailers [7]	Registration fees, other vehicles: Motorcycles [8]	Miscellaneous receipts: Total	Dealers licenses and plates	Operator and chauffeur permits	Certificates of title	Other miscellaneous items	Disposition of total receipts [9]: Collection and administration [10]	For construction and maintenance of: State highways	For construction and maintenance of: Local roads	State and county road bond payments [11]	For city streets	For other purposes
Alabama	$2,724,257	$2,676,873	[3] $2,096,223			[6] $580,650	[7] $35,620	[8] $2,200	$9,564	$1,765	$6,425		$1,374	$141,215	$987,359	$531,230	$1,064,453		
Arizona	647,816	534,044	276,478			257,566	24,047	1,029	88,696	1,165	12,435	$38,003	37,093	171,906	475,910				
Arkansas	1,768,850	1,622,457	[3] 1,165,907			[6] 456,550	[7] 114,050	[8] 4,020	28,323	6,080	16,732		5,511	[12] 76,369	1,069,042		623,439		
California	9,866,449	[2] 8,572,540	[2] 5,926,481			[2] 2,646,059	[2] 540,449	28,449	725,011	32,701	66,470	(13)	125,840	1,722,860	2,901,802	2,901,802	27,033		[14] $2,312,952
Colorado	2,035,608	1,554,754	1,208,768			345,986	11,979	1,434	467,441	16,480	35,796	96,243	318,922	138,730	604,357	609,765	145,000		[15] 537,756
Connecticut	7,850,589	5,936,579	4,481,119			1,455,460	40,183	8,940	1,864,887	76,005	1,247,944		540,938	[16] 1,017,681	6,832,908				
Delaware	1,014,333	857,576	612,844			244,732	10,619	1,063	145,075	5,840	104,838	27,629	6,768		799,182		[18] 215,151		
Florida	4,994,882	4,788,924	3,695,537		(17)	1,093,387	53,797	5,649	146,512	12,580	4,428	99,805	29,699	395,724					[19] 4,599,158
Georgia	1,036,241	989,092	835,669			153,423	17,893	2,869	26,387	5,646	10,174	513	10,054	137,716	898,525				
Idaho	1,401,849	1,360,553	1,017,410	$999,888	$17,522	343,143	15,053	1,427	24,816	14,220	508	(13)	10,088	104,659	124,590	1,172,600			
Illinois	16,229,327	15,544,450	11,685,116		(17)	3,859,334	120,803	14,606	549,468	48,688	210,981		289,799	[20] 272,127	5,598,990	1,030,235	8,249,560	$221,277	[21] 857,138
Indiana	7,846,883	6,922,464	3,905,707	3,833,609	72,098	3,016,757	153,341	5,122	765,956	45,300	447,469	125,529	147,658	268,851	3,789,016	1,515,606		378,902	[22] 1,894,508
Iowa	10,695,407	10,319,082	8,642,322			1,676,760	35,837	6,467	334,021	42,931	47,238		243,852	[23] 434,837	9,905,148				[24] 355,422
Kansas	3,056,837	2,939,865	[3] 2,227,915		(17)	[6] 711,950	[7] 26,930	[8] 3,332	86,710	19,376	20,855		46,479	198,699	1,058,138	1,800,000			
Kentucky	4,174,076	4,052,388	2,919,066	2,864,233	54,833	[25] 1,133,322	(25)	3,117	118,571	19,224	15,227		84,120	235,953	3,387,049	551,074			
Louisiana	4,052,816	3,691,661	2,832,173	2,770,824	61,349	859,488	273,256	4,191	83,708	12,220	63,837		7,651	130,264	3,602,252		320,300		
Maine	2,909,237	2,326,367	[3] 1,691,842			[6] 634,525	9,164	5,288	568,418	42,690	457,673		68,055	489,906	514,919		1,904,412		
Maryland	3,581,251	[2] 2,733,464	[2] 2,286,089			[2] 447,375	54,470	7,258	786,059	30,013	189,450	224,363	342,233	559,108	2,115,500			906,643	
Massachusetts	6,508,343	3,705,822	2,517,166	2,428,076	9,090	1,188,656	30,741	1,394	2,770,386	62,250	2,045,118		663,018	1,511,678	2,401,781	764,125	[18] 130,022	613,360	[26] 1,087,377
Michigan	18,560,314	17,002,776	13,344,020		(17)	3,658,756	491,638	10,359	1,055,541	53,260	318,492	418,226	265,563	793,502	10,144,796	6,000,000	1,082,060		[27] 539,956
Minnesota	6,366,982	6,196,749	4,682,034	4,588,857	93,177	1,514,715	66,494	5,450	98,289	24,480	54,016	285	19,508	298,176	2,805,476		[28] 2,825,082		[29] 438,248
Mississippi	1,870,396	1,823,179	[3] 1,317,640			[6] 505,539	[7] 15,700	[8] 2,040	29,477	1,588			27,889	99,606	102,638	1,668,152			
Missouri	9,356,828	8,745,460	[3] 7,676,372		(17)	[6] 1,069,088	[7] 42,800	[8] 7,040	561,528	46,809	115,197	265,600	133,922	331,322	1,590,906		7,434,600		
Montana	1,070,104	1,017,580	821,558		(17)	196,022	1,139	525	50,860	14,456	446	12,324	23,634	42,636		1,027,468			
Nebraska	1,721,834	1,599,853	1,097,162	1,082,488	14,674	502,691	21,630	1,584	98,767	11,588	13,568	11,436	62,175	71,761	495,022	1,155,051			
Nevada	299,634	287,920	198,041			89,879	3,341	349	8,024	2,318	(13)		5,706	43,087	81,297		175,250		
New Hampshire	2,167,421	1,764,161	[3] 1,154,031			[6] 610,130	[7] 23,000	5,299	374,961	21,147	283,306		70,508	97,554	2,069,867				
New Jersey	15,377,843	11,055,464	7,479,943	7,129,422	350,521	3,575,521	121,267	10,536	4,190,576	60,485	3,119,621	340,094	670,376	[30] 1,547,702	2,500,000	7,200,330	[31] 2,586,022		[32] 1,543,789
New Mexico	666,748	628,681	410,841	396,254	14,587	217,840	8,238	549	29,280	4,211		(13)	25,069	93,027	286,861	93,011			[33] 193,849
New York	42,318,407	37,713,329	26,241,861	25,470,431	771,430	11,471,468	315,235	46,213	4,243,630	197,445	2,911,781		1,134,404	[34] 3,396,003	8,475,142	5,764,872		3,885,805	[22] 20,796,585
North Carolina	5,356,126	4,915,234	4,107,366	3,908,445	198,921	807,868	313,660	4,260	122,972	17,498		96,596	8,878	[35] 179,335	[36] 1,247,480	1,193,852	[37] 2,676,848		[21] 58,611
North Dakota	1,382,008	1,338,366	1,025,564		(17)	312,802	1,388	1,226	41,028	7,795		31,373	1,860	[38] 92,564	14,554	174,890			[39] 1,100,000
Ohio	17,677,551	16,825,662	11,363,217		(17)	5,462,445	462,989	23,579	365,321	89,082	78,047		198,192	505,557	3,804,967	10,014,087		3,352,940	
Oklahoma	3,382,455	3,319,915	[3] 2,700,285			[6] 619,630	[7] 41,840	[8] 5,700	15,000	15,000				171,727	1,281,896	1,753,470		169,374	[22] 5,988
Oregon	[40] 5,337,137	5,092,302	[41] 4,081,122	4,033,280	47,842	[40] 1,011,180	32,550	5,061	207,224	24,707	64,896	84,398	33,223	282,668	2,069,429	1,148,637	1,548,769		[21] 287,634
Pennsylvania	29,184,792	21,587,486	14,814,281	14,289,453	524,828	6,773,205	149,392	26,979	7,420,935	289,745	4,368,174	1,123,594	1,639,422	3,881,577	16,988,326	(42)	3,487,583		[43] 4,827,306
Rhode Island	2,198,342	1,755,483	1,333,257	1,266,595	66,662	422,226	1,528	3,189	438,142	13,230	339,504		85,408	292,399	852,744	53,199			[44] 1,000,000
South Carolina	[45] 2,503,367	[2] 2,142,015	[2] 1,740,109			[2] 401,906	[2] 56,572	1,810	302,970	20,251	153,473	34,732	94,514	69,231	437,214		[46] 1,698,365		[47] 298,557
South Dakota	1,459,027	1,410,321	1,244,155	1,241,940	2,215	166,166	11,550	335	36,821	8,970		16,383	11,468	52,773	282,746	1,123,508			
Tennessee	[48] 2,940,010	2,824,327	[3] 2,365,822			[6] 458,505	[7] 43,239	[8] 4,256	68,188	15,721			52,467	120,617	1,336,720	1,336,720			[21] 145,953
Texas	12,747,489	12,019,908	8,410,082	8,336,031	74,051	3,609,826	260,235	13,426	453,920	31,290	170,190		252,440	632,834	3,898,417	8,216,238			
Utah	797,598	749,159	553,942			195,217	6,223	938	41,278	5,952	10,470	9,027	15,829	60,098			737,500		
Vermont	2,072,717	1,787,170	1,388,813	1,373,522	15,291	398,357	2,951	3,351	279,245	26,443	223,796		29,006	112,203	1,438,064	270,000	252,450		
Virginia	6,090,279	5,756,627	4,694,216	4,614,359	79,857	1,062,411	19,500	7,826	306,326	39,484	62,509	144,315	60,018	615,120	5,475,159				
Washington	2,482,758	1,850,765	1,106,624	1,059,592	47,032	744,141	50,486	4,286	577,221	15,344	418,650	136,798	6,429	409,480	1,401,114	510,594		13,670	[21] 147,900
West Virginia	3,837,922	3,523,186	2,723,231	2,612,751	110,480	799,955	9,678	4,330	300,728	27,083	109,493	96,306	67,846	148,988			3,688,934		
Wisconsin	9,768,006	9,455,019	7,137,743	6,941,281	196,462	2,317,276	153,900	11,169	147,918	6,594	15,129	3,735	122,460	767,594	4,008,995	2,213,254	[49] 1,339,657	343,835	[50] 1,094,671
Wyoming	679,411	666,932	471,413			195,519	[7] 500	[8] 525	11,454	7,244			4,210	13,574	499,837		166,000		
District of Columbia	625,508	155,971	133,118	125,443	7,675	22,853	1,112	808	467,617	2,253	240,926	70,677	153,761	85,238				[51] 540,270	
Total	302,694,065	266,139,955	195,841,695	(52)	(52)	70,298,260	4,298,007	320,853	31,935,250	1,596,647	18,075,282	3,507,984	8,755,337	23,316,236	120,656,135	61,793,770	42,378,490	10,426,076	44,123,358

1 Financial data only on this table.

2 Only registration fees are shown, except that in 3 States (as noted) certain special taxes are paid in lieu of registration fees and in such cases the special taxes are here included.

3 Reports from certain States do not segregate passenger vehicle fees. In such cases approximations have been made as noted.

4 Many States do not segregate public vehicles for hire, from privately owned passenger cars and returns are therefore incomplete.

5 Includes all passenger vehicles for hire such as taxis, U-Drive-It cars, livery cars, busses, ambulances, and hearses, if so classed by the State registration agency. Some States class busses with trucks and such cases are noted.

6 Certain States do not segregate truck registration and in such cases approximations have been made as noted.

7 Approximations have been made as noted.

8 Approximation based on 1932 special survey.

9 A new column has been added and headed "for city streets"; data were formerly under "other purposes."

10 Some States pay part or whole of administration expenses from State appropriation and such cases are noted.

11 Payments on State highway bond obligations, except as noted.

12 Includes extra amount for special auditing.

(*Footnotes continued on following page.*)

[13] No fees charged.
[14] Includes $1,681,002 for State motor police, and $631,950 for motor-vehicle reserve fund.
[15] Includes $109,381 for State general fund diverted from State highway fund; $288,785 from extra $1 assessment on each motor vehicle registered and credited to county pension funds; and $139,590 diverted from county road fund for police pension fund.
[16] Includes refunds of $201,094.
[17] Bus fees included with truck fees.
[18] Bond payments from combined fund of gasoline taxes and motor-vehicle fees and are prorated between them.
[19] For county school fund.
[20] For 6-month period.
[21] For State highway patrol.
[22] For State general fund.
[23] Includes $106,482 to counties for refunds.
[24] Includes $21,614 for State general fund and $333,808 to county funds.
[25] Trailers classed with trucks and not separable.
[26] Includes $605,861 to State general fund, which amount with the amount allocated from gasoline taxes, make the total $8,028,320 for unemployment relief; for State police expenses, $296,900; and the remainder for miscellaneous nonroad purposes.
[27] Includes $221,464 for highway police, and $318,492 to State general fund.
[28] Includes $1,481,832 payments on county bonds.
[29] To State general fund, $360,000.
[30] Includes $1,188,430 for administration formerly paid by State appropriation.
[31] Repayment of loan.
[32] Includes $175,000 to free bridge commission, $400,000 for Bayonne bridge, and $968,789 in closed banks and not assignable.
[33] Includes $95,620 to State general fund and $98,229 to county funds.
[34] Excludes $1,291,458 paid from State general fund; includes $2,491,684 refunds of surtax paid (pursuant laws 1932) and refunded (pursuant laws 1933); remainder county clerk fees.
[35] Includes $96,596 from certificate of title fees for auto-theft prevention and recovery fund.
[36] Includes $664,544 which it is anticipated will be appropriated for State highways.
[37] Includes $147,056 county loan repayment.
[38] Includes $56,057 rebates for overcharges, due to reduction in fees.
[39] Transfer to real estate bond payment fund, not used for highway purposes.
[40] Covers registration year ending June 30, 1933.
[41] Light delivery trucks reported by State as passenger vehicles. Estimated fees for these trucks deducted from passenger cars and added to trucks.
[42] Included with State highway funds, not reported separately.
[43] Includes $4,042,235 paid on State debt obligations, $624,554 for highway patrol, $87,555 for State employees' retirement board, and remainder for miscellaneous expenses.
[44] For relief aid to cities and towns.
[45] Data covers 10 months to Oct. 31 due to change in registration year.
[46] Includes $1,273,939 payments on county bonds.
[47] Includes $213,919 for State highway patrol, and remainder for operating expenses of motor transport division of railroad commission.
[48] Excludes refunds on licenses of $463,024 due to reduction of registration fees.
[49] Payments on county road bonds.
[50] Allotment to counties in lieu of personal property taxes on motor vehicles, used to lower county taxes.
[51] Includes $75,473 for street signals; the remainder for streets as appropriated by Congress.
[52] Total not shown as less than half the States do not segregate private and public vehicles.

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

CLASS 1.—PROJECTS ON THE FEDERAL-AID HIGHWAY SYSTEM OUTSIDE OF MUNICIPALITIES

AS OF AUGUST 31, 1934

STATE	APPORTIONMENTS		COMPLETED				UNDER CONSTRUCTION				APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS	
	Sec. 204 of the Act of June 16, 1933 (1934 Fund)	Act of June 18, 1934 (1935 Fund)	Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	Estimated Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds
Alabama	$4,123,000	$2,129,921	$2,359,732	$1,305,902		100.4	$4,167,871	$2,339,025	—	253.7	$238,941		29.1	$239,132	$2,129,921
Arizona	3,878,555	1,338,712	2,468,228	2,421,498		176.1	1,990,270	1,424,949		118.9				32,108	1,338,712
Arkansas	3,374,167		954,076	828,012		31.5	2,662,979	2,244,432		137.1	189,489		5.1	112,234	
California	7,912,928	3,966,103	4,736,362	3,559,590		175.6	6,501,997	4,229,795		139.5				123,543	3,966,103
Colorado	3,437,265	1,743,003	2,432,060	2,411,800		119.5	1,114,321	985,753		31.4		$239,657	19.0	39,712	1,503,346
Connecticut	1,404,213	607,500	189,823	189,823		3.0	1,385,153	1,213,805		27.8	584				607,500
Delaware	909,544	461,697	319,586	317,492		7.3	564,607	564,607		10.7		387,793	14.4	27,446	73,904
Florida	2,519,010	1,330,671	2,532,194	1,857,220		86.1	676,287	564,997		29.9	20,185		.6	76,608	1,330,671
Georgia	5,045,592	2,556,745	1,904,552	1,892,583		123.4	2,254,580	2,239,606		153.0	183,266		10.4	730,138	2,556,745
Idaho	2,166,858	1,131,910	1,132,998	1,089,288		123.1	984,108	966,211		52.3	5,180	110,022	10.8	106,179	1,021,888
Illinois	4,585,971	3,060,041	582,802	582,136		14.3	3,348,871	3,348,871		37.7	963,160		5.3	91,804	3,060,041
Indiana	5,018,921		589,079	589,079		25.5	3,792,054	3,792,054		99.3	371,531		14.0	266,258	
Iowa	5,027,830	2,217,361	2,166,551	2,086,800		125.8	3,161,917	2,920,430		143.3		58,780	34.7	20,600	2,158,581
Kansas	5,044,802	2,558,837	3,041,582	3,037,735		330.3	2,264,672	1,990,590		67.5	16,476	6,562	4.2		2,552,275
Kentucky	3,751,605	1,527,324	2,042,206	2,026,751		160.3	1,535,000	1,375,661		85.1	307,268		9.0	41,926	1,527,324
Louisiana	2,914,295		742,275	741,044		29.3	2,413,992	1,907,341		48.6	23,133		.7	242,780	
Maine	1,617,560	793,644	671,109	665,698		25.2	876,580	846,424		18.9				105,438	793,644
Maryland	1,782,263	289,610	156,306	146,657		4.8	948,030	948,030		16.5	632,827	124,112	13.8	54,749	165,498
Massachusetts	1,101,716		679,177	496,986		18.9	738,165	527,406		18.9				77,325	
Michigan	6,113,389	3,226,284	1,046,200	1,046,200		45.4	4,824,725	4,775,725		222.7	39,600			251,864	3,226,284
Minnesota	4,561,011	2,642,244	2,969,881	2,932,318		604.5	1,649,485	1,620,921		161.8	7,772				2,642,244
Mississippi	3,489,337	2,301,148	1,324,173	692,326		68.9	3,887,867	2,138,327		204.4	279,537		33.4	379,147	2,301,148
Missouri	5,237,532	2,778,183	1,687,001	1,369,015		75.5	3,761,252	3,532,726		126.8	142,147	513,117	24.0	193,644	2,265,066
Montana	4,463,849	2,714,208	3,501,615	3,315,066		273.1	1,645,007	1,138,661		127.7				10,122	2,714,208
Nebraska	3,914,481	1,982,182	3,195,168	2,459,984		265.4	1,892,738	1,452,821		96.2	1,676		1.2		1,982,182
Nevada	2,909,367	1,350,356	1,786,345	1,786,345		199.3	1,154,132	1,107,183		65.5	15,000	123,035	8.9	859	1,227,321
New Hampshire	725,739	484,731	602,305	595,769		9.7	142,375	129,970		1.5					484,731
New Jersey	3,099,371		137,255	137,255		7.0	3,037,598	2,882,677		40.1	3,846			75,593	
New Mexico	2,846,648	1,470,850	2,380,112	2,236,182		250.7	554,324	554,324		23.5		111,645	33.8	56,142	1,359,205
New York	10,271,846	2,872,521	2,742,975	2,217,390		53.1	10,083,361	7,977,101	$163,900	197.2	23,198	2,355,000	39.9	54,158	353,621
North Carolina	4,761,147	2,420,471	1,920,481	1,463,973		176.0	2,788,791	2,553,105		432.8	268,618		23.0	475,451	2,420,471
North Dakota	2,902,224	1,469,483	2,225,649	2,078,880		800.1	933,742	677,206		175.7	114,157		44.0	31,982	1,469,483
Ohio	7,277,758	3,539,256	3,498,716	3,444,333		100.8	4,130,948	3,772,933		91.1				60,492	3,539,256
Oklahoma	4,608,399	2,342,590	2,338,452	2,312,351		164.2	1,870,419	1,870,419		133.6	168,753		6.2	256,875	2,342,590
Oregon	3,053,448	1,548,906	2,093,778	1,876,545		126.2	1,266,023	1,150,740		57.3	13,619			12,543	1,548,906
Pennsylvania	6,691,194	4,554,082	1,434,527	1,432,138		44.1	5,391,697	5,051,393		87.5	32,258			175,404	4,554,082
Rhode Island	979,367		363,973	363,973		9.5	632,057	569,189		11.0				46,204	
South Carolina	2,729,583	1,385,477	420,290	420,290		36.7	2,094,852	2,092,122		187.2	114,867		5.8	102,304	1,385,477
South Dakota	3,005,739		1,452,930	1,357,681		259.3	1,628,994	1,300,320		218.8	179,369		49.3	168,369	
Tennessee	4,246,309	2,105,453	2,381,895	1,989,973		106.7	2,186,046	2,003,234		73.6	87,790		8.4	165,312	2,105,453
Texas	11,588,643		7,146,472	6,235,064		696.0	4,690,100	4,482,502		313.4	250,502		5.2	620,575	
Utah	2,374,205	1,066,345	1,646,781	1,634,539		154.7	776,074	695,715		40.9		630,000	83.4	43,951	436,345
Vermont	928,184	466,042	220,712	218,837		13.8	727,931	698,677		31.0	10,670	31,535	3.3		434,507
Virginia	3,708,379	1,882,693	2,246,847	2,190,769		108.5	1,317,916	1,208,295		30.5	93,686		8.5	215,629	1,882,693
Washington	3,057,934	1,553,206	1,765,642	1,760,626		73.0	1,252,529	1,252,529		32.8	15,918	303,286	10.1	28,861	1,249,920
West Virginia	2,013,405	1,140,167	766,411	766,411		25.8	1,185,809	1,179,809		46.5	48,955		.1	18,230	1,140,167
Wisconsin	4,615,429	2,223,827	2,423,865	2,392,313		108.0	2,227,870	2,148,125		120.8	49,156		1.3	25,835	2,223,827
Wyoming	2,250,663	1,143,856	1,467,177	1,278,956		285.5	1,266,366	938,426	240,571	213.3	12,361	393,440	59.0	20,920	509,845
District of Columbia															
Hawaii	1,683,956		196,115	144,003		10.5	1,724,330	1,389,715		25.1	144,921		4.1	5,316	
TOTALS	185,724,651	76,377,640	87,084,441	78,395,596		6,832.4	112,106,772	96,774,877	404,471	5,080.4	4,670,416	5,387,984	624.0	5,883,762	70,585,185

NOTE: THE APPORTIONMENT AND BALANCE OF 1935 FUNDS ARE INCOMPLETE SINCE THE ASSIGNMENT OF FUNDS TO THE THREE CLASSES HAD NOT BEEN RECEIVED FROM ALL STATES ON AUGUST 31.

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

CLASS 2.—PROJECTS ON EXTENSIONS OF THE FEDERAL-AID HIGHWAY SYSTEM INTO AND THROUGH MUNICIPALITIES

AS OF AUGUST 31, 1934

STATE	APPORTIONMENTS		COMPLETED				UNDER CONSTRUCTION				APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS	
	Sec. 204 of the Act of June 16, 1933 (1934 Fund)	Act of June 18, 1934 (1935 Fund)	Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	Estimated Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds
Alabama	$2,175,100	$1,064,961	$395,168	$395,168		9.4	$1,445,005	$1,445,005		45.6	$297,599		8.6	$37,328	$1,064,961
Arizona	807,982	305,191	428,304	428,304		10.3	191,147	191,147		2.7	138,121		.3	50,411	305,191
Arkansas	1,889,534		537,998	505,683		16.9	1,164,932	1,082,775		25.7	300,722		1.3	353	
California	4,213,986	1,983,052	2,594,265	2,290,546		33.1	2,262,548	1,854,388		19.6				69,051	1,983,052
Colorado	1,718,633	871,501	1,384,382	1,337,363		27.1	360,951	360,951		7.8	20,319		.2		871,501
Connecticut	802,407	426,500	455,441	455,441		5.4	349,036	345,893		4.8				1,072	426,500
Delaware	454,772	230,849	151,147	142,866		1.4	311,906	311,906		6.0		$48,713	.7		182,136
Florida	1,405,008	665,336	690,329	483,407		8.1	944,211	913,240		10.0	8,361		.8		665,336
Georgia	2,724,620	1,278,373	503,475	503,207		22.2	1,242,875	1,242,875		41.1	34,835		1.1	943,703	1,278,373
Idaho	1,197,829	321,126	527,716	516,119		11.3	628,416	612,538		7.0		2,643	1.3	69,173	318,483
Illinois	7,718,839	2,515,835	1,859,312	1,858,572		25.5	5,295,434	5,295,434		44.6	447,971		1.4	116,862	2,515,835
Indiana	4,416,651		419,385	417,801		11.5	2,753,981	2,753,981		53.3	881,158		8.3	363,711	
Iowa	2,815,585	1,311,000	1,086,700	1,039,245		32.6	1,064,438	1,007,670		17.1	323,600	3,420	5.7	445,070	1,307,580
Kansas	2,522,401	1,279,419	1,802,400	1,797,997		31.9	868,976	724,122		5.2	282	651	.4		1,278,768
Kentucky	1,927,828	954,578	395,648	387,265		10.2	924,875	920,648		18.2	438,496		2.9	181,419	954,578
Louisiana	1,457,148		463,626	463,626		10.1	975,697	949,104		15.9	44,418		1.0		
Maine	909,878	490,045	443,434	441,228		9.6	395,558	394,662		7.1				73,988	490,045
Maryland	891,132	452,514	16,789	12,639		.6	385,808	385,808		3.6	268,000		.4	224,685	452,514
Massachusetts	5,007,199		129,536	87,991		3.8	4,697,400	4,672,424		12.8	127,088			119,696	
Michigan	3,438,781	1,613,142	692,000	692,000		9.2	2,727,320	2,712,670		32.2	27,650			6,461	1,613,142
Minnesota	3,719,143	1,421,494	1,636,657	1,624,792		71.3	1,538,554	1,523,082		29.0	29,358		.5	541,912	1,421,494
Mississippi	1,744,669	885,057	190,463	178,003		6.4	848,185	848,185		28.8	113,733		4.5	604,748	885,057
Missouri	4,019,501	1,543,435	985,269	951,647		30.6	2,671,193	2,253,278		24.8	202,870	95,145	5.5	611,707	1,448,290
Montana	1,115,962	113,092	684,821	684,821		20.8	375,553	375,553		11.3	45,118		3.8	10,470	113,092
Nebraska	1,957,240	991,091	647,890	645,868		20.0	1,264,539	1,264,539		13.0	33,507		.2	13,327	991,091
Nevada	500,051	100,000	93,177	93,177		2.5	359,775	359,775		5.7	28,068		.6	19,031	100,000
New Hampshire	706,640	242,366	379,645	364,160		7.9	300,206	300,206		7.7				42,274	242,366
New Jersey	3,190,118		312,610	312,610		4.7	2,848,820	2,794,687		18.1				82,820	
New Mexico	1,674,158	735,425	883,746	883,746		24.6	533,981	533,981		8.5	75,947		.7	180,484	735,425
New York	8,449,487	4,203,000	1,334,673	1,334,292		17.0	7,001,468	6,480,635	$4,400	45.4	530,908	669,000	4.5	103,652	3,529,600
North Carolina	2,380,573	1,210,235	1,204,676	1,201,286		47.5	610,821	609,329		26.3	437,304		6.0	132,655	1,210,235
North Dakota	1,451,112	734,742	518,689	518,513		21.8	376,226	375,640		15.4	473,289		19.5	83,669	734,742
Ohio	4,335,686	2,359,503	1,882,297	1,687,401		27.8	2,979,930	2,632,467		31.6				15,817	2,359,503
Oklahoma	2,304,200	1,171,295	777,614	776,493		19.2	1,211,340	1,211,340		23.1	146,881		3.1	169,486	1,171,295
Oregon	1,526,724	774,454	575,342	558,520		13.7	860,536	859,867		14.1	30,941		.6	77,496	774,454
Pennsylvania	4,854,988	2,397,703	2,021,106	1,969,024		37.1	2,356,591	2,325,431		21.5	265,800		1.2	294,733	2,397,703
Rhode Island	579,625		306,462	306,462		5.0	234,782	234,782		2.4				38,381	
South Carolina	1,364,791	692,738	256,555	256,555		7.5	818,502	818,097		32.6	77,402		1.6	212,736	692,738
South Dakota	1,502,870		532,236	532,236		16.6	602,503	602,503		21.8	46,225		2.4	321,905	
Tennessee	2,123,155	1,121,790	974,805	974,666		15.0	639,458	639,458		8.3	387,926		4.2	121,105	1,121,790
Texas	6,642,863		2,191,753	2,060,617		74.9	3,191,482	3,168,006		37.7	945,074		5.5	469,166	
Utah	771,826	533,173	618,072	602,012		14.0	54,016	53,423		2.8		10,805	1.5	116,391	522,368
Vermont	500,509	240,611	239,815	231,472		6.8	286,368	269,037		7.8					240,611
Virginia	2,008,458	941,347	873,275	851,707		20.4	940,697	750,189		3.9	275,975		2.8	130,588	941,347
Washington	1,977,260	776,603	1,584,672	1,567,700		29.4	377,994	377,994		3.0		78,518	1.4	31,566	698,085
West Virginia	1,342,270	570,085	169,068	169,068		4.1	1,044,214	1,019,869		15.5	106,562		.9	46,772	570,085
Wisconsin	2,684,067	1,235,459	1,205,225	1,191,458		34.0	1,437,855	1,409,793		17.8				82,816	1,235,459
Wyoming	1,125,332	571,928	342,527	342,024		8.4	775,045	774,461		15.5	8,847	3,485	.7		568,443
District of Columbia	959,235	389,537	530,052	530,052		3.2	440,028	423,044		1.5		263,281	1.9	6,139	126,256
Hawaii															
TOTALS	116,007,826	41,719,585	38,930,247	37,656,850		902.4	65,971,146	63,465,892	4,400	875.2	7,620,255	1,175,661	108.0	7,264,829	40,539,524

NOTE: THE APPORTIONMENT AND BALANCE OF 1935 FUNDS ARE INCOMPLETE SINCE THE ASSIGNMENT OF FUNDS TO THE THREE CLASSES HAD NOT BEEN RECEIVED FROM ALL STATES ON AUGUST 31.

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

CLASS 3.—PROJECTS ON SECONDARY OR FEEDER ROADS

AS OF AUGUST 31, 1934

STATE	APPORTIONMENTS		COMPLETED				UNDER CONSTRUCTION				APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS	
	Sec. 204 of the Act of June 16, 1933 (1934 Fund)	Act of June 18, 1934 (1935 Fund)	Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	Estimated Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds
Alabama	$2,072,033	$1,064,960	$89,081	$89,081		5.7	$1,469,612	$1,469,612		109.0	$425,376		32.8	$87,964	$1,064,960
Arizona	525,423	998,032	114,319	114,154		7.1	418,007	406,045		35.1				5,223	998,032
Arkansas	1,484,634		61,397	61,304		26.9	1,149,455	1,149,455		120.3	10,393		1.7	263,482	
California	3,480,440	1,983,051	1,748,119	1,415,673		42.0	2,178,978	1,881,673		135.9	11,205		.7	171,889	1,983,051
Colorado	1,718,632	871,502	1,454,003	1,421,217		146.0	390,583	269,699		33.8				27,716	871,502
Connecticut	659,120	420,868					664,916	659,120		14.5					420,868
Delaware	454,772	230,849	20,825	20,825			181,855	181,855		9.1	93,632	$106,799	29.1	158,460	124,050
Florida	1,307,816	665,336	491,178	489,237		33.4	788,332	788,332		41.6				30,247	665,336
Georgia	2,320,973	1,278,373	485,119	485,119		37.2	744,569	744,569		66.1	325,875		21.1	765,410	1,278,373
Idaho	1,121,562	824,450	872,874	801,066		107.7	329,000	320,496		34.2		75,000	15.4		749,450
Illinois	5,265,960	3,345,525	910,202	910,202		77.2	4,143,169	4,143,169		241.3	212,589		3.8		3,345,525
Indiana	602,271						532,893	532,893		68.9				69,378	
Iowa	2,212,245	1,590,000	484,478	467,800		87.0	2,110,572	1,687,820		231.3	46,750	142,000	75.1	9,875	1,448,000
Kansas	2,522,401	1,279,419	959,962	959,721		92.9	1,556,240	1,556,240		69.7	6,440		1.7		1,279,419
Kentucky	1,837,926	1,336,409	1,164,252	1,155,636		146.6	683,648	682,263		69.0				27	1,336,409
Louisiana	1,457,148		121,405	121,405		9.2	1,080,400	1,080,400		37.1	94,566		13.0	160,776	
Maine	842,479	427,897	817,320	786,853		76.1	101,373	45,007		4.5				10,618	427,897
Maryland	891,132	1,067,934	371,629	371,629		27.8	454,951	441,025		31.7	45,445	171,816	9.7	33,033	896,118
Massachusetts	488,185		141,634	141,634		5.3	328,108	328,108		9.9				18,444	
Michigan	3,184,057	1,613,142	284,400	284,400		27.9	2,771,330	2,756,430		198.8	26,600		1.1	116,627	1,613,142
Minnesota	2,376,415	1,361,813	1,065,604	1,048,705		149.4	1,239,947	1,239,947		73.1	5,000		1.5	82,764	1,361,813
Mississippi	1,744,669	354,022					1,188,215	1,188,215		128.0	192,182		24.2	364,272	354,022
Missouri	2,923,273	1,852,122	1,438,071	1,429,558		347.0	1,402,407	1,402,291		153.2	4,361	210,517	95.7	87,063	1,641,605
Montana	1,859,937	942,434	1,460,735	1,460,735		190.3	407,643	397,194		35.8				2,008	942,434
Nebraska	1,957,240	991,091	620,311	611,311		103.4	1,299,033	1,298,783		174.8		156,007	101.7	47,145	835,084
Nevada	1,136,479	852,000	956,915	956,915		96.1	135,888	115,888		9.1	24,475	81,638	35.0	39,202	770,362
New Hampshire	477,460	242,365	306,170	265,346		13.7	212,038	212,038		12.0				76	242,365
New Jersey	56,550		56,550	56,550		.5									
New Mexico	1,272,129	735,425	683,923	683,923		130.3	562,192	562,192		163.8				26,014	735,425
New York	3,608,768	4,252,400	1,097,521	994,646		29.8	2,977,100	2,603,625	$38,700	70.2		2,034,705	41.3	10,497	2,178,995
North Carolina	2,380,573	1,210,235	996,150	995,751		72.1	988,216	984,331		134.8	279,570		21.1	120,920	1,210,235
North Dakota	1,451,112	734,742	63,050	63,050		20.5	396,081	396,081		101.4	357,037		112.5	634,945	734,742
Ohio	3,871,148	1,966,253	1,791,762	1,743,547		245.9	2,333,080	2,070,178		59.7				57,423	1,966,253
Oklahoma	2,304,199	1,171,295	273,213	273,213		61.2	2,000,210	1,927,820		207.8	55,479		4.1	47,688	1,171,295
Oregon	1,526,724	774,454	1,088,797	983,147		80.8	611,466	530,471		27.6	12,342			765	774,454
Pennsylvania	7,344,822	2,639,003	2,126,647	2,126,235		221.9	5,242,308	5,156,645		431.4	61,942		5.7		2,639,003
Rhode Island	439,716		90,572	90,572		7.8	321,893	321,893		25.4				27,251	
South Carolina	1,364,791	692,739	170,490	170,490		14.2	1,096,017	1,096,017		130.4	98,284		9.2		692,739
South Dakota	1,502,870		541,647	541,647		162.2	468,800	468,800		139.0	411,985		134.2	80,438	
Tennessee	2,123,155	1,075,748	607,601	607,601		53.3	1,239,819	1,239,819		90.4	129,444		6.8	146,291	1,075,748
Texas	6,012,518		3,896,634	3,326,005		556.1	2,483,866	2,312,563		210.6	112,500		.3	261,450	
Utah	1,048,677	533,173	686,131	634,909		127.5	438,182	413,768		39.3		177,612	51.3		355,561
Vermont	438,880	241,354	78,416	78,340		5.2	407,640	360,540		31.5		55,593	3.8		185,761
Virginia	1,699,920	941,347	869,596	827,227		129.2	822,671	793,782		75.8	31,152		.3	47,759	941,347
Washington	1,080,673	776,603	569,212	558,731		36.0	486,933	486,933		27.7	27,739		3.9	7,269	776,603
West Virginia	1,118,559	570,083	92,206	92,206		4.3	832,729	832,729		46.4	50,000		3.2	143,624	570,083
Wisconsin	2,425,385	1,482,551	1,511,598	1,451,554		94.2	815,778	753,989		73.4	94,957		6.1	124,884	1,482,551
Wyoming	1,125,332	571,928	838,100	820,061		127.1	252,544	245,353		21.2	59,918	15,352	13.7		556,576
District of Columbia	959,234	584,305	401,558	401,558		4.2	557,471	557,471		3.6		159,204	.9	205	425,101
Hawaii	187,106						177,718	177,718		4.9				9,389	
TOTALS	92,267,523	46,547,232	34,971,377	33,390,489		4,040.2	53,475,876	51,271,285	38,700	4,264.1	3,307,238	3,386,243	881.7	4,298,511	43,122,289

NOTE: THE APPORTIONMENT AND BALANCE OF 1935 FUNDS ARE INCOMPLETE SINCE THE ASSIGNMENT OF FUNDS TO THE THREE CLASSES HAD NOT BEEN RECEIVED FROM ALL STATES ON AUGUST 31.

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

SUMMARY OF CLASSES 1, 2, AND 3.

AS OF AUGUST 31, 1934

STATE	APPORTIONMENTS		COMPLETED				UNDER CONSTRUCTION				APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS	
	Sec. 204 of the Act of June 16, 1933 (1934 Fund)	Act of June 18, 1934 (1935 Fund)	Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	Estimated Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds
Alabama	$8,370,133	$4,259,842	$2,843,981	$1,790,151		115.6	$7,082,489	$5,253,643		408.3	$961,916		70.4	$364,424	$4,259,842
Arizona	5,211,960	2,641,935	3,010,851	2,963,956		193.6	2,599,424	2,022,142		156.7	138,121		.2	87,742	2,641,935
Arkansas	6,748,335	3,428,049	1,553,471	1,395,000		75.4	4,977,366	4,476,662		283.1	500,604		8.1	376,069	3,428,049
California	15,607,354	7,932,206	9,078,746	7,265,810		250.7	10,943,494	7,965,856		295.0	11,205		.7	364,483	7,932,206
Colorado	6,874,530	3,486,006	5,270,445	5,170,380		292.6	1,865,855	1,616,402		73.0	20,319	$239,657	19.2	67,428	3,246,349
Connecticut	2,865,740	1,454,868	645,265	645,265		8.4	2,399,105	2,218,819		47.1	584			1,072	1,454,868
Delaware	1,819,088	923,395	491,558	481,183		8.7	1,058,367	1,058,367		25.8	93,632	543,305	44.2	185,906	380,090
Florida	5,231,834	2,661,343	3,713,700	2,829,863		127.7	2,408,831	2,266,570		81.6	28,546		1.4	106,855	2,661,343
Georgia	10,091,185	5,113,491	2,893,146	2,880,909		182.7	4,242,024	4,227,050		260.2	543,975		32.6	2,439,251	5,113,491
Idaho	4,486,249	2,277,486	2,533,588	2,406,472		242.0	1,941,524	1,899,245		93.5	5,180	187,665	27.4	175,352	2,089,821
Illinois	17,570,770	8,921,401	3,352,316	3,350,910		117.0	12,787,474	12,787,474		323.6	1,223,720		10.6	208,666	8,921,401
Indiana	10,037,843	5,088,963	1,008,464	1,006,879		37.0	7,078,928	7,078,928		221.6	1,252,689		22.3	699,347	5,088,963
Iowa	10,055,660	5,118,361	3,737,730	3,593,845		245.4	6,336,927	5,615,920		391.6	370,350	204,200	115.4	475,545	4,914,161
Kansas	10,089,604	5,117,675	5,803,946	5,795,453		455.1	4,689,888	4,270,952		142.4	23,199	7,212	6.3		5,110,463
Kentucky	7,517,359	3,818,311	3,602,105	3,569,651		317.1	3,143,523	2,978,572		172.3	745,763		12.0	223,372	3,818,311
Louisiana	5,828,591	2,963,932	1,327,306	1,326,073		48.7	4,470,089	3,936,845		101.7	162,118		14.7	403,556	2,963,932
Maine	3,369,917	1,711,586	1,931,863	1,893,780		110.9	1,373,510	1,286,093		30.5				190,044	1,711,586
Maryland	3,564,527	1,810,058	544,724	530,925		33.2	1,788,789	1,774,863		51.7	946,272	295,928	23.9	312,467	1,514,130
Massachusetts	6,597,100	3,350,474	950,346	726,610		27.9	5,763,673	5,527,937		41.6	127,088			215,465	3,350,474
Michigan	12,736,227	6,452,568	2,022,600	2,022,600		82.5	10,323,375	10,244,825		453.7	93,850		1.1	374,952	6,452,568
Minnesota	10,656,569	5,425,551	5,672,142	5,605,815		825.2	4,427,985	4,383,949		264.0	42,130		2.0	624,676	5,425,551
Mississippi	6,978,675	3,540,227	1,514,635	870,329		75.3	5,924,267	4,174,727		361.2	585,453		62.1	1,348,167	3,540,227
Missouri	12,180,306	6,173,740	4,110,341	3,750,219		453.1	7,834,853	7,188,295		304.9	349,378	818,779	125.3	892,414	5,354,961
Montana	7,439,748	3,769,734	5,647,171	5,460,622		484.2	2,428,203	1,911,408		174.7	45,118		3.8	22,600	3,769,734
Nebraska	7,828,961	3,964,364	4,463,369	3,717,162		388.8	4,456,310	4,016,143		284.1	35,183	156,007	103.1	60,472	3,808,357
Nevada	4,545,917	2,302,356	2,836,437	2,836,437		297.9	1,649,794	1,582,845		80.3	67,543	204,673	44.4	59,092	2,097,683
New Hampshire	1,909,839	969,462	1,288,119	1,225,275		31.3	654,619	642,214		21.2				42,350	969,462
New Jersey	6,346,039	3,220,879	506,416	506,416		12.2	5,886,418	5,677,364		58.2	3,846			158,413	3,220,879
New Mexico	5,792,935	2,941,700	3,947,780	3,803,851		405.5	1,650,497	1,650,497		195.8	75,947	111,645	34.5	262,640	2,830,055
New York	22,330,101	11,327,921	5,175,169	4,546,328		99.9	20,061,928	17,061,361	$207,000	312.9	554,106	5,058,705	85.7	168,307	6,062,216
North Carolina	9,522,293	4,840,941	4,121,307	3,661,011		295.6	4,387,789	4,146,765		593.9	985,492		50.1	729,026	4,840,941
North Dakota	5,804,448	2,938,967	2,807,387	2,660,442		842.4	1,706,049	1,448,927		292.5	944,483		176.0	750,596	2,938,967
Ohio	15,484,592	7,865,012	7,172,775	6,875,282		374.5	9,443,958	8,475,578		182.3				133,732	7,865,012
Oklahoma	9,216,798	4,685,180	3,389,279	3,362,057		244.5	5,081,969	5,009,579		364.4	371,113		13.3	474,049	4,685,180
Oregon	6,106,896	3,097,814	3,757,918	3,418,211		220.7	2,738,025	2,541,078		99.0	56,802		.7	90,804	3,097,814
Pennsylvania	18,891,004	9,590,788	5,582,279	5,527,397		303.1	12,990,596	12,533,469		540.5	360,001		6.9	470,137	9,590,788
Rhode Island	1,998,708	1,014,572	761,008	761,008		22.3	1,188,731	1,125,864		38.8				111,836	1,014,572
South Carolina	5,459,165	2,770,954	847,335	847,335		58.3	4,009,371	4,006,237		350.3	290,554		16.6	315,040	2,770,954
South Dakota	6,011,479	3,047,643	2,526,813	2,431,564		438.1	2,700,298	2,371,623		379.5	637,579		185.9	570,712	3,047,643
Tennessee	8,492,619	4,302,991	3,964,301	3,572,240		175.1	4,065,323	3,882,511		172.3	605,160		19.4	432,708	4,302,991
Texas	24,244,024	12,291,253	13,234,859	11,621,687		1,327.1	10,365,448	9,963,071		561.7	1,308,075		11.0	1,351,191	12,291,253
Utah	4,194,708	2,132,691	2,950,983	2,871,460		296.2	1,268,272	1,162,905		83.0		818,417	136.2	160,342	1,314,274
Vermont	1,867,573	948,007	538,943	528,649		25.8	1,421,939	1,328,254		70.3	10,670	87,128	7.1		860,879
Virginia	7,416,757	3,765,387	3,989,719	3,869,703		258.1	3,081,284	2,752,266		110.2	400,812		11.7	393,976	3,765,387
Washington	6,115,867	3,106,412	3,919,526	3,887,057		138.4	2,117,456	2,117,456		63.4	43,657	381,804	15.5	67,696	2,724,608
West Virginia	4,474,234	2,280,335	1,027,685	1,027,685		34.2	3,062,753	3,032,407		108.3	205,516		4.1	208,626	2,280,335
Wisconsin	9,724,881	4,941,837	5,140,688	5,035,325		236.2	4,481,503	4,311,908		212.0	144,113		7.4	233,535	4,941,837
Wyoming	4,501,327	2,287,712	2,647,805	2,441,041		421.0	2,293,954	1,958,240	240,571	290.0	81,126	412,278	73.4	20,920	1,634,863
District of Columbia	1,918,469	973,842	931,610	931,609		7.4	997,499	980,515		5.1		422,485	2.9	6,344	551,357
Hawaii	1,871,062	949,778	196,115	144,003		10.4	1,902,048	1,567,433		29.9	144,921		4.1	14,705	949,778
TOTALS	394,000,000	200,000,000	160,986,065	149,442,935		11,775.0	231,553,794	211,512,054	447,571	10,219.7	15,597,909	9,949,888	1,613.7	17,447,102	189,602,541

PUBLICATIONS of the BUREAU OF PUBLIC ROADS

Any of the following publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D.C. As his office is not connected with the Department and as the Department does not sell publications, please send no remittance to the United States Department of Agriculture.

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Report of the Chief of the Bureau of Public Roads, 1927. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1928. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1929. 10 cents.

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Report of the Chief of the Bureau of Public Roads, 1932. 10 cents.

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No. 583D . . Reports on Experimental Convict Road Camp, Fulton County, Ga. 25 cents.

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No. 1279D . . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922. 15 cents.

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No. 93MC . . Direct Production Costs of Broken Stone. 25 cents.

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No. 76MP . . The results of Physical Tests of Road-Building Rock. 25 cents.

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No. 1036Y . . Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Ohio (1927).

Report of a Survey of Transportation on the State Highways of Vermont (1927).

Report of a Survey of Transportation on the State Highways of New Hampshire (1927).

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio (1928).

Report of a Survey of Transportation on the State Highways of Pennsylvania (1928).

Report of a Survey of Traffic on the Federal-Aid Highway Systems of Eleven Western States (1930).

A complete list of the publications of the Bureau of Public Roads, classified according to subject and including the more important articles in PUBLIC ROADS, may be obtained upon request addressed to the U.S. Bureau of Public Roads, Willard Building, Washington, D.C.